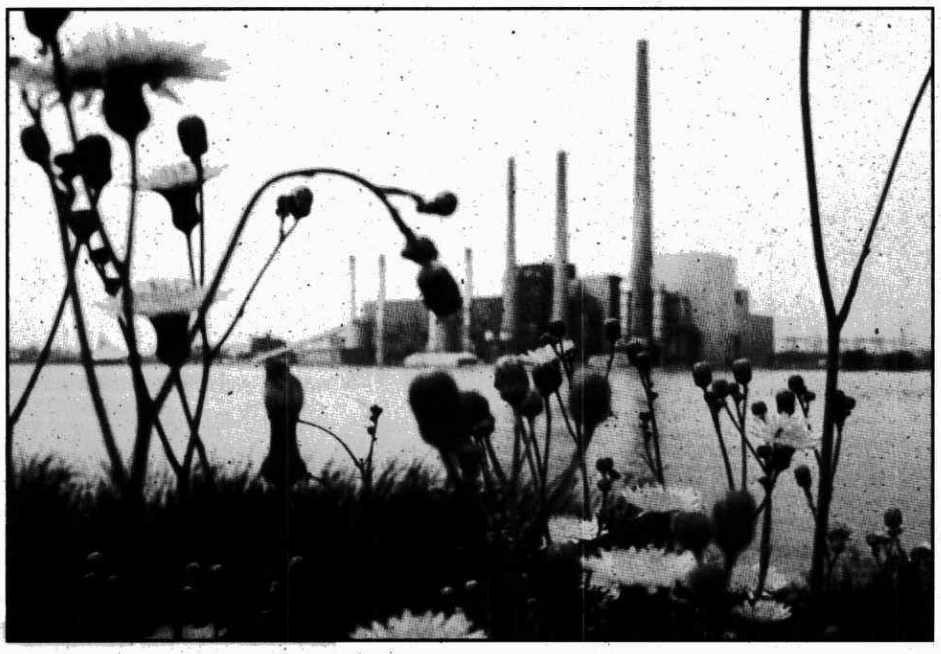
Air Quality in Ontario 1991

AIR QUALITY AND METEOROLOGY SECTION • AIR RESOURCES BRANCH



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Air Quality in Ontario 1991

A review of the Ministry of the Environment air quality monitoring program for 1991

FIGURES

Executive Summary

This is the twenty-first annual report documenting air quality in Ontario. New additions include a brief ambient air quality comparison of selected North American and international cities, a discussion of selected regional air quality problem areas, a comparison of air quality levels in southern versus northern Ontario and a detailed reference list.

The Ontario routine air monitoring network reached its maximum size of 450 instruments in 1980. Since then, the number of monitoring instruments has been reduced by 14 percent to a total of 387 instruments in 1991: 262 continuous monitors and 125 Hi-vol particulate samplers.

Undesirable air quality (when the measured ground level air concentration of a pollutant exceeds the Ambient Air Quality Criteria, *Regulation 337 of the EPA*) was measured on a number of occasions during 1991. For continuously monitored contaminants, ozone (O_3), suspended particles (SP), and total reduced sulphur compounds (TRS) were the contaminants which exceeded the provincial air quality criteria (AQC) most frequently. The 1-hour O_3 AQC was exceeded for at least one hour at 44 out of 48 O_3 stations (92%); 24 out of 32 TRS stations (75%) reported exceedances of the 1-hour TRS pulp mill AQC; and the 24-hour AQC for SP was exceeded at 21 out of 44 locations (48%) during 1991. Exceedances for sulphur dioxide (SO_2) were recorded at 16 out of 70 monitoring locations.

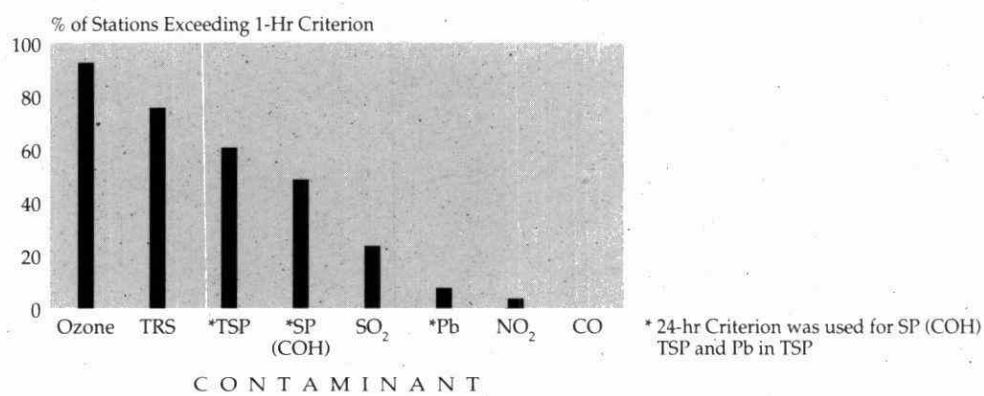
Undesirable air quality levels were also reached on a number of occasions for the 24-hour averaged total suspended particulate (TSP) concentrations. Out of 125 hi-volume stations, 76 (60%) recorded at least one exceedance of the 24-hour TSP AQC during the year. Five sites (all located near lead processing plants) recorded exceedances of the 24-hour lead (Pb) AQC while one exceedance of the 24-hour nickel (Ni) AQC was measured at the Port Colborne site during 1991.

Twenty-year trends in air quality show significant decreases in average levels of Pb (99%), carbon monoxide (CO;75%), SO_2 (75%), and TSP (49%). Nitrogen dioxide (NO_2) levels have decreased by 17% over a 17-year period while O_3 levels have increased by the same amount over the past 13-year period. For the corresponding emission levels in Ontario, the trend in SO_2 emissions shows a 70% decrease over the twenty-year period while over the past decade CO and oxides of nitrogen (NO_x) emissions show decreases of 30 and 10% respectively. These decreases are linked to specific pollution reduction and abatement activities.

The Air Pollution Index (API) derived from a combination of SO_2 and SP, is still the basis of the alert system for air pollution control in Ontario. The advisory level of 32 was reached on only one occasion during 1991. A maximum API of 34 dominated by suspended particles was recorded at the Hamilton Downtown site on May 23.

Results from the Air Quality Index (AQI) system show that during 1991, moderate (AQI between 32

Undesirable Air Quality in 1991
Based on Exceedance of Ontario AQC



* 24-hr Criterion was used for SP (COH) TSP and Pb in TSP

and 49) to poor (AQI between 50 and 99) air quality was recorded for at least 1 hour at all AQI sites. The frequency of days on which at least 1-hour of moderate air quality was recorded ranged from 1 to 58% depending on the site. Elevated levels of O_3 and SP were the most frequent cause of high index readings at the majority of AQI sites across Ontario.

The Lambton Industrial Meteorological Alert (LIMA), which is the basis of a SO_2 alert system for a section of Lambton county (including Sarnia) in southwestern Ontario, was issued on 8 occasions in 1991. The LIMA is issued when measured ground level SO_2 concentrations averaged over the previous 24 hours exceed 70 ppb and the weather conditions resulting in these high values are predicted to persist for at least 6 more hours. The longest duration of the alert was 62 hours, lasting from October 23 at 1600 Eastern Standard Time (EST) to October 26 at 0600 (EST).

Ambient air quality levels for the criterion contaminants (SO_2, CO, NO_2, TSP and O_3) were compared for selected North American and International cities for the most recent comparable year, 1989. Canadian cites in the comparison were Toronto, Montreal and Vancouver.

A southern versus northern Ontario air quality comparison showed that the greater presence of high temperature combustion sources including the automobile, power plants and incinerators in high density urban areas account for the higher level of contaminants in southern Ontario.Air quality in selected problem areas within Ontario is discussed in four case studies ie; particulates in Hamilton; SO_2 in Sudbury; CO in downtown Toronto and TRS in Fort Frances.

Meteorological conditions such as wind speed and direction, atmospheric stability, slow moving or stalled high pressure systems, and air temperatures play a major role in the occurrence of elevated concentrations of various contaminants. Variations in pollutant concentrations from day to day are mostly due to meteorological factors.

Ozone is formed by photochemical reactions in the atmosphere in the presence of nitrogen oxides, hydrocarbons and sunlight. In north eastern U.S. and Canada including southern Ontario, ozone episodes are a regional phenomenon. In 1991, there were 31 ozone episode days which is significantly more than the 17 and 13 episode days for 1989 and 1990 respectively but, less than the 36 recorded in 1988.

The 8-hour running mean for ozone was computed for the period 1988 to 1991. It was found that during episode events the 8-hour ozone running mean reached the Occupational Health and Safety Act threshold limit value of 100 parts per billion (ppb) on several occasions, primarily at rural sites.

Introduction

Ambient Air Monitoring

Ambient air monitoring in Ontario provides information on the actual concentration of selected pollutants in various communities. This information is used:

- To assess the quality of the air in Ontario and evaluate trends.
- To inform the public on a real-time basis so they can respond appropriately to pollutant levels.
- To provide an episode warning and control mechanism for the protection of human health.
- To assess the effectiveness of pollution reduction and abatement activities.
- To provide the basis for the development of air management strategies.
- To determine the progress in meeting Ontario's air quality criteria.
- To identify areas of non-attainment.
- To quantify the amount of pollution reduction required to meet the criteria.
- To provide quantitative measurements for abatement action on specific sources.
- To enable the setting of meaningful air quality criteria.
- To assist in the assessment of damage to vegetation and structure caused by air pollution.
- To support research activities on the effects of pollutants on health, property and vegetation.

The initial network established by the Air Pollution Control Division of the Ministry of Health in the early 1960s consisted of twenty hi-volume (Hi-vol) samplers for the measurement of particulate matter and several lead peroxide and lime candles for the measurement of sulphur dioxide and fluorides.

In 1965, a meteorological program was developed in order to document atmospheric conditions. The initial program consisted of two 300 ft (91 m) meteorological towers equipped at three levels to provide wind speed, wind direction and temperature.

In 1966 the sampling network was expanded to include automatic sampling for gaseous contaminants such as sulphur dioxide, oxides of nitrogen, total oxidants, carbon monoxide and total hydrocarbons.

With the passage of the Air Pollution Control Act in 1967, the task of air pollution control was centralized in an agency of the provincial government and by 1971 a total of 76 sampling sites (260 instruments) were operating across the province. In 1991, the provincial monitoring network consisted of 387 instruments: 262 continuous monitors at 99 sites and 125 Hi-vol samplers. Meteorological monitoring was carried out at 34 locations in 1991.

It should be noted that the province maintains three other monitoring networks throughout Ontario: the urban toxics network which monitors the levels of volatile and semi-volatile organic compounds in urban areas; the toxic deposition network which monitors the atmospheric deposition of pesticides and other semivolatile organic compounds, as well as trace metals into the Great Lakes basin; and finally, the acid deposition network which monitors the effects of emissions abatement on acid deposition across the province. Information pertaining to these three networks is available elsewhere.[1]

This report describes the 1991 Ontario routine air quality monitoring program including a summary of the measurements of gases and particulate matter as well as a summary of meteorological conditions during the year. It is intended to be used in conjunction with the Appendix which appears in a separate volume. The characteristics, effects, Ontario criteria (if any), sources, method of monitoring, locations and frequency of sampling are discussed for each of the gaseous and particulate contaminants.

New additions to this year's report include a comparison of air quality levels in northern versus southern Ontario, a discussion of regional air quality problem areas, a brief ambient air quality comparison of selected North American and international cities for 1989, and a detailed reference list.

[1] Contact for Information is, Special Studies/Research Management Unit, Air Resources Branch, 125 Resources Road, Etobicoke, Ontario M9P 3V6, Tel. (416) 235-6155

The ambient air quality data collected from the Ontario Ministry of the Environment monitoring network have been subjected to stringent quality control and quality assurance programs. The purpose of these programs is to ensure that the air quality data collected by the Ministry have attained acceptable levels of accuracy, precision and completeness. Section A of this report gives a brief discussion of the quality assurance and quality control procedures as well as a description of the data base.

The entire continuous (hourly) network is summarized in Appendix Table A-1 and Maps 1 and 2. This table gives station name, number, and an indication of the "continuous" pollutants measured. Letter codes indicate whether data were telemetered or chart-read.

The "continuous" measured contaminants include SP (suspended particles) measured in coefficient of haze (COH) units as well as the following gases:

SO_2	(sulphur dioxide)
CO	(carbon monoxide)
O_3	(ozone)
NO_2	(nitrogen dioxide)
NO	(nitric oxide)
NO_x	(oxides of nitrogen)
THC	(total hydrocarbons)
RHC	(reactive hydrocarbons)
TRS	(total reduced sulphur)

Section B of this report describes each of the "continuous" contaminants in sequence. Section C deals with the Air Quality Index system, the four-year history of the Air Pollution Index and a brief summary of the Lambton Industrial Meteorological Alert system.

The (daily) particulate (Hi-vol) network is summarized in Appendix Table A-2 and Maps 4 and 5. This table provides station name, number, and the various "daily" pollutants measured. Also, numerals indicate the monitoring cycle frequency in days. Some additional codes are defined in the key at the top of the table. The main particulate contaminants measured are:

TSP	(total suspended particulate)
IP	(inhalable particulate)
Cd in TSP	(cadmium)
Cr in TSP	(chromium)
Fe in TSP	(iron)
Mn in TSP	(manganese)
Ni in TSP	(nickel)
Pb in TSP	(lead)
V in TSP	(vanadium)
Cu in TSP	(copper)
NO_3^- in TSP	(nitrate)
SO_4^{2-} in TSP	(sulphate)

Section D describes each of the "daily" or particulate contaminants under the headings of TSP, IP, Lead, Trace Metals, Nitrate and Sulphate. These data are typically collected at a frequency of once every 1, 3 or 6 days.

The (monthly) dustfall and fluoridation networks are summarized in Appendix Table A-3. This table provides station name, number and the various "monthly" parameters measured. The main "monthly" contaminants measured are:

TDF	(total dustfall)
FLR	(fluoridation rate)

Section E describes each of the "monthly" contaminants under the headings TDF and FLR. These data are collected at a frequency of once every month.

Section F of this report depicts the provincial trends in air quality and emissions and also provides a brief comparison of air quality levels in selected cities around the world, compares air quality levels in northern versus southern Ontario and discusses air quality in selected problem areas within Ontario.

The meteorological network is described in Appendix Table A-5 and Maps 6 and 7. The table provides station name, numerical identifier, the various meteorological parameters measured as well as the height above ground at which the measurements are taken.

Section G summarizes the general meteorological conditions for 1991 and presents a discussion of ozone levels.

Section H provides a reference list.

Queries relating to this report or requests for data (magnetic tape or hard copy) should be addressed to:

Quality Assurance,
Telemetry and Analysis Unit
Air Resources Branch
125 Resources Road
Etobicoke, Ontario
M9P 3V6
Telephone: (416) 235-5780
or (416) 235-5778

GLOSSARY

COH - the coefficient of haze measurement yields an estimate of the amount of fine suspended particulate matter by measuring the amount of light transmission.

Criterion - a desirable maximum ambient air concentration or level (based on potential effects).

Detection limit - the minimum concentration of a compound contaminant that can be determined by a specified analytical method.

Geometric mean - a statistic of a data set calculated by taking the nth root of the product of all (n) values in a data set.
- provides a better indication than arithmetic mean of the central tendency for a small data set with extreme values.

Percentile value - the percentage of the data set that lies below the stated value.
- for example, if the 70 percentile value is 0.10 ppm, then 70% of the data are below 0.10 ppm.

Primary pollutant - a contaminant which is directly emitted to the atmosphere.

Secondary pollutant - a contaminant which is formed from other pollutants present in the atmosphere.

Correlation coefficient - a measure of the strength of the relationship between two variables.

"Continuous" pollutant - a contaminant for which a continuous record exists; effectively, pollutants which have hourly data (maximum 8760 values per year).

"Daily" pollutant - a contaminant for which there exists only a 24-hour or daily value (maximum 365 values per year).

"Monthly" pollutant - a contaminant for which there exists only a monthly (30-day) value (maximum 12 values per year).

ABBREVIATIONS

AQC - air quality criterion
COH - coefficient of haze reported for SP
ppb - parts (of contaminant) per billion (parts of air)
ppm - parts (of contaminant) per million (parts of air)
$\mu g/m^3$ - micrograms (of contaminant) per cubic metre (of air)
$gm/m^2/30$ days - grams (of contaminant) deposited per square metre per 30-day period
$\mu g/100\ cm^2$/month - micrograms (of contaminant) per 100 square centimetres per month
NAAQC - National Ambient Air Quality Criterion
USEPA - United States Environmental Protection Agency
TLV - threshold limit value
UV - ultraviolet radiation

Section A - Monitoring Network Operations

1.0 Network Description

In 1971 the provincial monitoring network consisted of 254 instruments: 166 continuous analyzers at 76 monitoring sites and 88 sites with Hi-vol samplers. By 1980, the provincial network had reached its maximum size at 450 instruments of which 268 were continuous analyzers at 106 sites and 182 Hi-vol monitors. Since 1980, the total number of instruments operating across Ontario has decreased by about 14%. In 1991, the network consisted of 387 instruments: 262 continuous monitors distributed at 99 sites to monitor up to nine different gaseous contaminants, and Hi-vols at 125 sites. Figure 1a shows the distribution of the number of instruments operating in Ontario since 1971 while Figure 1b displays the number of continuous monitors in cities/towns in Ontario which have a population in excess of 100,000.

The Ministry of the Environment is divided into six Regions. Each Region has an Air Resources Unit which is responsible for the day-to-day operation and maintenance of the air monitoring analyzers. Through the computer telephone line system, the technicians remotely check the automatic "zero" and "span" values each day to determine the stability of the instruments. The span gases used for these daily checks are assigned concentration values by the Instrumentation and Quality Assurance Unit of the Air Resources Branch.

Regional technicians perform regular inspections and maintenance on the monitoring equipment and stations. If an instrument undergoes major servicing, the Instrumentation and Quality Assurance Unit may be requested to perform an audit to confirm proper operation of the analyzer.

Portable calibration equipment is used by regional staff in evaluating instrument performances. The portable calibrators are calibrated by the Instrumentation and Quality Assurance Unit a minimum of twice per year.

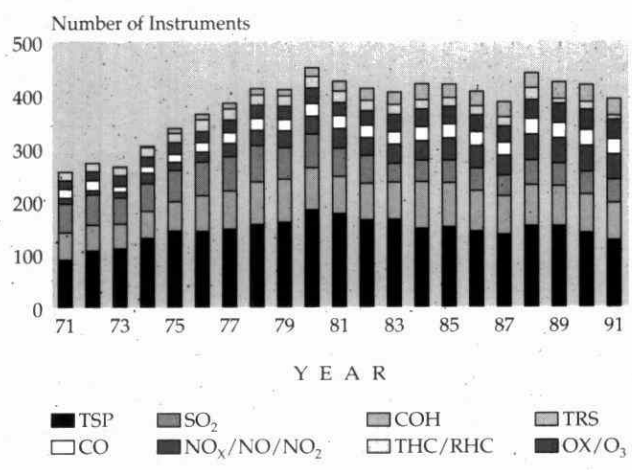
1.1 Quality Assurance and Quality Control

The Air Resources Branch maintains a laboratory with gas reference standards that adhere to the U.S. National Institute of Standards and Technology (NIST) as well as to the Pollution Measurement Division of Environment Canada. Performance audits are performed on the SO_2, NO/NO_2, O_3 and TRS (as H_2S) monitors three times per year and on CO and hydrocarbon (as methane) monitors once per year. Hi-vol and PM-10 samplers are audited annually to determine the accuracy of the flow rate measurements. Deviation of ±10 percent from the audit standard is the criterion for performance acceptability.

The ambient air quality monitoring network is subjected to continuous maintenance and quality control programs.

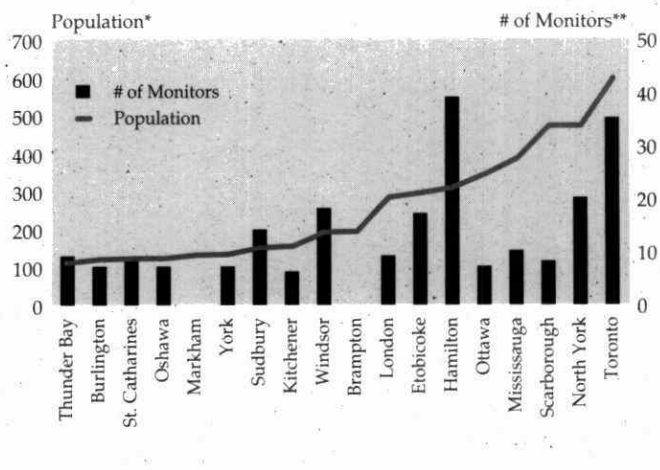
The real-time continuous and particulate air quality data are constantly reviewed, assessed and validated by Regional staff and staff of the Air

Figure 1a:
Ontario Ambient Air Quality Monitoring Program from 1971 to 1991



Does not include meteorological sensors and urban air toxics monitoring

Figure 1b:
Continuous Monitoring in Cities/Towns in Ontario with a Population of 100,000*



* 1988 Population in Thousands

** # of Continuous Monitors (1990)

Resources Branch. Remedial actions are taken immediately to rectify any problems that may affect the validity of the data.

In 1991, the Provincial continuous air monitoring instruments were subjected to 795 performance audits. 80.8% of the audits were found to be within the acceptable performance criterion of ±10%. For the remaining 19.2% which fell outside the 10% criterion, station log records and backup charts were consulted to correct data. As a result, the MOE monitoring network for 1991 had 95.5% valid data (See Figure 2a).

The Hi-Vols were subjected to 222 performance audits in 1991. Eighty-six percent of the audited instruments were within the ±10% of the acceptable criterion. (See Figure 2b).

1.2 Data Base

The ambient air quality data used in this report are stored in MOE's Air Quality Information System (AQUIS). Approximately 4 million air pollution measurements are added to AQUIS on an annual basis with the vast majority representing the more heavily populated urban areas within Ontario.

Two statistical tests, the pattern test and the gap test, are used as a final data screening procedure to identify data anomalies. The pattern test checks for unusual pollutant behaviour. A set of limits for each pollutant has been defined from historical data. Values that are outside these limits are flagged for further investigation. The gap test identifies possible data anomalies by examining the length of the distance between the two largest values, the second and the third largest values, and similarly for other gaps.

The AQUIS data are divided into three major groupings: continuous (1-hour) measurements, daily (24-hour) measurements, and monthly (30-day) measurements.

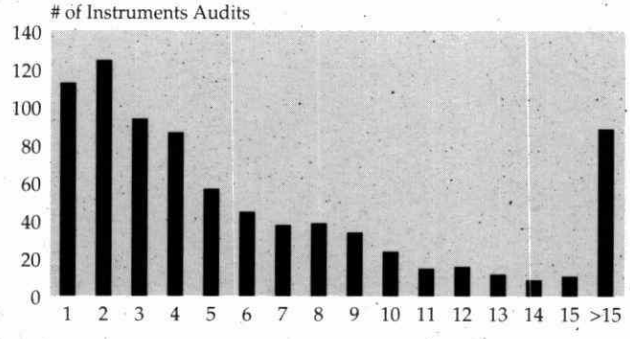
The hourly data are obtained from ambient air monitoring instruments that operate continuously, producing a measurement every hour for a possible total of 8760 hourly measurements in a year. A valid annual mean requires at least 5840 hourly readings or 67% valid data.

The daily measurements are obtained from instruments that provide one measurement per 24-hour period and are typically operated on a 1,3 or 6 day sampling schedule. Such instruments are used to measure total suspended particulates, inhalable particulate, lead, various trace metals, sulphate and nitrate. For daily data, a valid annual mean requires at least two thirds of the total number of possible samples, i.e., a station operating on a 6-day sampling schedule would require at least 40 out of a possible 61 samples.

The monthly data are collected over a 30-day period producing 12 monthly measurements per year. A valid annual mean requires at least seven out of a possible 12 values.

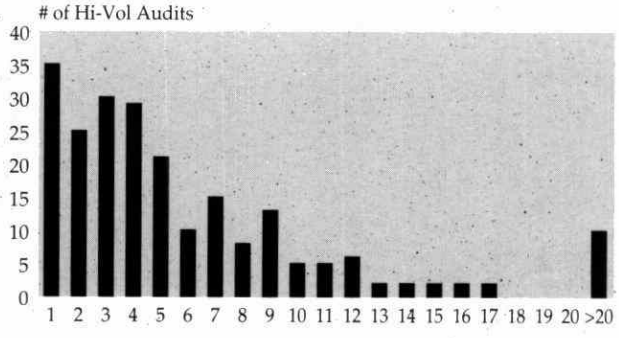
In order for a monitoring site to have been included in the 10-year trend analysis the site had to have a valid annual mean for at least 8 out of the 10 years 1982-1991, and to be included in the "long term" 20-year trend analysis the site had to have a valid mean for at least 18 out of the 20-years 1972-1991.

Figure 2a:
Continuous Monitors Audit Results 1991



Note: Acceptable performance criterion is 10%

Figure 2b:
Hi-Vol Flow Audit Results 1991



Note: Acceptable performance criterion is 10%

Section B - Pollutants Measured by Continuous Monitors (Hourly Data)

SO_2

SULPHUR DIOXIDE

2.1 Characteristics

SO_2 is a colourless gas with a strong, pungent odour at concentrations over 0.5 ppm. Sulphur dioxide can be oxidized (either photochemically or in the presence of a catalyst) to sulphur trioxide (SO_3). In the presence of water vapour, SO_3 is readily converted to sulphuric acid mist. Other basic oxides combine with SO_3 to form sulphuric aerosols. Sulphuric acid droplets and other sulphates are thought to account for about 5 to 20 percent of the total suspended particulate in urban air. These compounds can be transported large distances and come back to earth as a major constituent of acid precipitation. Many of the health problems attributed to SO_2 may be the result of the oxidation of SO_2 to other compounds.

2.2 Effects

1 hour average

less than .16 ppm - no known effects
0.16 ppm - injurious to sensitive species of vegetation in combination with ozone
0.26 ppm - injurious to sensitive vegetation
0.34 ppm - odourous, increasing vegetation damage
2.00 ppm - increasing sensitivity to individuals with asthma and bronchitis

The enhancement by particulate matter of the toxic response to sulphur dioxide has been observed under conditions which would promote the conversion of SO_2 to sulphuric acid. A twofold to threefold increase in the instant response to SO_2 is observed in the presence of particulate matter capable of changing SO_2 in the presence of water vapour to sulphuric acid. Sulphuric acid inhalation causes an increased in the respiratory systems mucous secretions, which reduces the system's ability to remove particulates via mucociliary clearance. This can result in an increased incidence of respiratory infection.

2.3 Ontario Criteria

0.25 ppm (1-hour)
0.10 ppm (24-hours)
0.02 ppm (1-year)

2.4 Sources

Approximately 75% of the SO_2 emitted in Ontario originates from non-ferrous smelters and electric utilities. A major fraction of the remaining 25 percent comes from other industrial sources including iron ore smelters, petroleum refineries, pulp and paper mills and area sources including residential, commercial and industrial space heating (Figure 3). Reduction of SO_2 pollution levels can generally be achieved through the use of low sulphur content fuels or the use of chemical sulphur removal systems.

2.5 Method of Monitoring

Fluorescent excitation of SO_2 by pulsed ultra-violet radiation.

2.6 Locations of Monitors

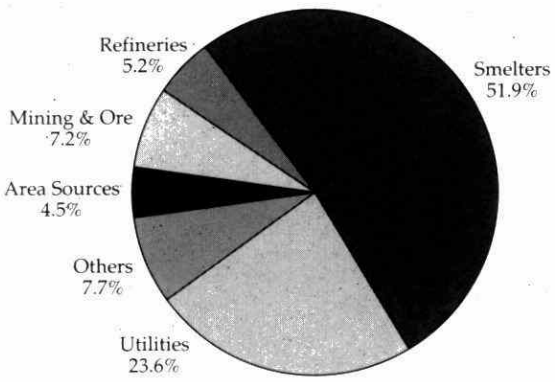
The Appendix provides a description of the provincial SO_2 network (Table A-1). SO_2 monitoring was conducted at 70 locations in 1991.

2.7 Monitoring Results

The distribution by percentile of the hourly data, the annual average, and the maximum one-hour and 24-hour (midnight to midnight) values are provided in the Appendix (Table A-6). Also given are the number of exceedances of the sulphur dioxide criteria (see Section 2.3).

The lowest annual average SO_2 level in the province was measured in Thunder Bay (63200), where the hourly SO_2 readings never exceeded 0.04 ppm.

Figure 3:
Ontario SO_2 Emissions by Sectors
(Annual Emission 1,400 kT)



The highest annual mean (0.014 ppm) was recorded at the Copper Cliff site in northeastern Ontario near the Inco smelter operations and at the Beach Boulevard site in Hamilton near the city's industrial area. The greatest number of exceedances (64) of the 1-hour criterion occurred at the Copper Cliff site (77218). The Balmertown site in northwestern Ontario near the Campbell Red Lake gold mine recorded two exceedances of the SO_2 24-hour criterion.

There was a total of 16 SO_2 stations (12 in the Sudbury basin area) throughout the province where the hourly SO_2 criterion was exceeded at least once and six where the 24-hour criterion was exceeded. There were no exceedances of the annual criterion during 1991. (See Table 1).

SP

SUSPENDED PARTICLES

3.1 Characteristics

SP is defined as a relative measure of suspended particulate matter of size most likely to reach the lungs (diameter less than 5-10 microns). It is determined by the amount of soiling caused by the trapping of particles on a filter medium.

3.2 Effects

1 hour average

less than 2.0 COH units - no known effects
2.0 COH units - decrease in visibility
4.0 COH units - soiling evident
6.0 COH units - increasing sensitivity to individuals with asthma and bronchitis

3.3 Ontario Criteria

1.0 COH unit (24-hours)
0.5 COH unit (1-year)

3.4 Sources

Industrial processes which include combustion, incineration, construction, mining, metal smelting, processing and grinding. In the urban airshed, motor vehicle exhaust and road dust are the major sources of this material. Natural sources include wind-blown soil, forest fires, ocean spray, and volcanic activity.

3.5 Method of Monitoring

Continuous paper tape sampler with sampling inlet and flow rate regulated to favour small airborne particles.

SP is determined by drawing a measured volume of air through a portion of paper tape which moves through an automated sampling unit to produce a reading every hour. The reduction of light transmitted through the tape is expressed as coefficient of haze (COH) per 1,000 linear feet of air sampled.

3.6 Locations of Monitors

The Appendix provides a description of the provincial SP network (Table A-1).

Suspended particles were measured at 44 locations in 1991.

3.7 Monitoring Results

The distribution by percentile of the hourly data, the annual average, the maximum one-hour and 24-hour values, and the number of exceedances of the SP criteria (see Section 3.3) are provided in the Appendix (Table A-7).

The lowest annual levels measured in the province were at Guelph (28028), Cornwall (56051) and Sudbury (77203) where the SP averaged 0.17 units.

The greatest number of exceedances (35) of the 24-hour criterion and the highest annual mean (0.61 unit) occurred at the Mission site (31049), 381 Yonge Street, in an urban street canyon in Toronto. The highest measured value (4.7 units) was recorded at the College Street monitor (12016) in Windsor and at the Mission site (31049) in Toronto.

There was a total of 21 stations (48%) where the 24-hour criterion was exceeded at least once and two where the one-year criterion was exceeded. (See Table 1).

TRS

TOTAL REDUCED SULPHUR COMPOUNDS

4.1 Characteristics

The characteristics are malodours similar to rotten eggs or rotten cabbage.

4.2 Effects

1 hour average

less than 5 ppb - no known effects
5 ppb - odour threshold
27 ppb - extremely odourous
1,000 ppb - sensitive individuals may suffer nausea and headache due to severe odour

4.3 Ontario Criteria

Methyl Mercaptans - 10 ppb (1-hour)
Hydrogen Sulphide - 20 ppb (1-hour)
Total Reduced Sulphur (from Kraft Pulp Mills) - 27 ppb (1-hour)

4.4 Sources

The industrial sources include the steel industry, pulp and paper mills, and refineries and the natural sources include swamps, bogs, and marshes.

4.5 Method of Monitoring

Reduced sulphur compounds are oxidized to SO_2 in a high temperature converter and the SO_2 concentration is measured using fluorescent excitation by ultra-violet radiation.

4.6 Locations of Monitors

The Appendix provides a description of the provincial TRS compounds network (Table A-1).

TRS monitoring was carried out at 32 locations in 1991.

4.7 Monitoring Results

The distribution by percentile of the hourly data, the annual average, and the one-hour and 24-hour maxima are provided in the Appendix (Table A-8).

The lowest average levels measured in the province were at Tiverton (18007) on the western shore of Lake Huron. The highest annual mean (4.4 ppb), the greatest number of exceedances (379) of the 1-hour TRS pulp mill AQC and the highest 1-hour value (236 ppb) were recorded at Terrace Bay (63093) in northwestern Ontario near a kraft pulp mill (See Table 1).

CO

CARBON MONOXIDE

5.1 Characteristics

Colourless, odourless, tasteless and poisonous gas which is produced as a result of incomplete combustion of carbonaceous fuels. It is of concern as an air pollutant because it has a strong affinity for haemoglobin and thus reduces the ability of blood to transport oxygen.

5.2 Effects

1 hour average

less than 30 ppm - no known effects

30 ppm - increased cardiovascular symptoms for smokers with heart disease

50 ppm - increasing cardiovascular symptoms for non-smokers with heart disease. Some visual impairment.

The health threat is most serious for those who suffer from cardiovascular disease. Exposure to elevated levels is associated with impairment of visual perception, learning ability, manual dexterity and performance of complex tasks.

5.3 Ontario Criteria

30 ppm (1-hour)
13 ppm (8-hours)

5.4 Sources

The primary source of CO (about 75%) is from the transportation sector. A secondary source is fossil fuel combustion for residential space heating and commercial/industrial operations (Figure 4).

5.5 Method of Monitoring

Non-dispersive infrared photometry based on the preferential absorption of infrared radiation by CO.

5.6 Locations of Monitors

The Appendix provides a description of the provincial CO network (Table A-1).

CO was monitored at 28 stations in 1991.

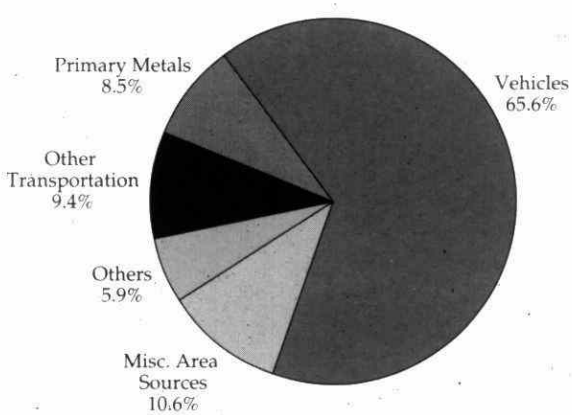
5.7 Monitoring Results

The distribution by percentile of the hourly data, the mean, and the maximum one-hour and eight-hour values are given in the Appendix (Table A-9).

The lowest annual average (0.2 ppm) was measured at Sarnia (14064) and North Bay (75010) while the highest annual average (2.1 ppm) was recorded at the Mission site (31049) in Toronto. The highest measured one-hour (24 ppm) and eight-hour (15 ppm) values were also recorded at the Mission site. This monitor is located in the Yonge Street corridor exposing it to motor vehicle exhaust.

There were no exceedances of the Ontario one-hour (30 ppm) criterion; however, the eight-hour (13 ppm) criterion was exceeded on two occasions at the Mission site (31049) in downtown Toronto. (See Table 1).

Figure 4:
Ontario CO Emissions by Sectors
(Annual Emission 2,500 kT)



THC/RHC

HYDROCARBONS

6.1 Characteristics

Hydrocarbon compounds are primarily methane (colourless, odourless) which is present at about 1.5 ppm in the ambient atmosphere. Non-methane hydrocarbons (or reactive hydrocarbons) are usually present at much lower levels. This fraction reacts with nitrogen oxides and other oxidants in the presence of sunlight to form ozone.

6.2 Effects

Effects depend on the individual chemical compound which the analytical technique cannot identify.

6.3 Ontario Criteria

There is no Ontario AQC for THC. However, criteria and standards exist for specific hydrocarbons and other organics.

6.4 Sources

Natural sources include trees and other vegetation and decay of animal and plant material.

Anthropogenic sources include motor vehicles, gasoline storage tanks, petroleum and chemical industries, landfill sites, paint manufacturing, application and fermentation sites.

6.5 Method of Monitoring

Calibrated flame ionization detector.

6.6 Locations of Monitors

The Appendix provides a description of the provincial THC/RHC network (Table A-1).

RHC was monitored at 1 location while THC was monitored at 7 locations in 1991.

6.7 Monitoring Results

The distribution by percentile of the hourly data; the mean; and the maximum one-hour and 24-hour values are given in the Appendix (Tables A-10 and A-11).

The locations and values for the lowest, and highest means are given in Table 1. The highest one-hour maximum concentration of reactive hydrocarbon compounds (2.6 ppm) was measured in Hamilton (the only site where the measurement is made) while the highest 1-hour THC value (20.0 ppm) for the year was measured in Oakville (44015).

NO_2

NITROGEN DIOXIDE

7.1 Characteristics

Nitrogen gas (N_2) is an abundant and inert gas which makes up almost 80 percent of the earth's atmosphere. In this form, it is harmless to man and essential to plant metabolism. Due to its abundance in the air, it is a frequent component in many combustion processes. When combustion temperatures are extremely high, as in the burning of coal, oil, gas and in automobile engines, atmospheric nitrogen (N_2) may combine with O_2 to form the various oxides of nitrogen (NO_x). Of these, nitric oxide (NO) and nitrogen dioxide (NO_2) are the most important contributors to air pollution.

NO_2 is a reddish-brown gas with a pungent and irritating odour over 0.10 ppm. It is an oxidation product of nitric oxide (NO) which is the primary NO_x emission. NO_2 reacts with hydrocarbons in sunlight to form ozone, and with water to form nitric acid, a component of acid rain.

7.2 Effects

1 hour average

less than 0.10 ppm - no known effects

0.10 ppm - odour threshold

0.25 ppm - some increase in bronchial reactivity in asthmatics

0.52 ppm - increasing sensitivity to individuals with asthma and bronchitis

7.3 Ontario Criteria

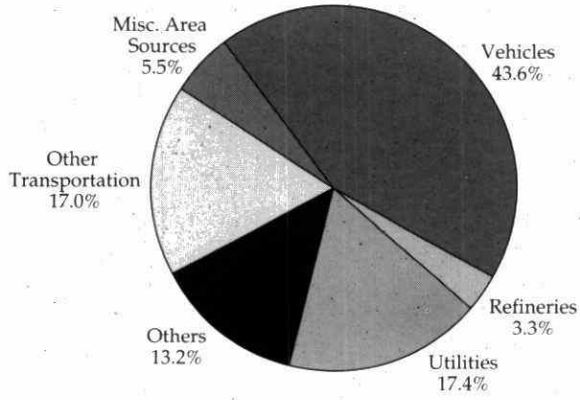
0.20 ppm (1-hour)

0.10 ppm (24-hour)

7.4 Sources

Anthropogenic sources of high temperature combustion processes including automobiles, power

Figure 5:
Ontario NO_X Emissions by Sectors
(Annual Emission 550 kT)



plants, incinerators and several chemical processes. In Ontario, the transportation sector accounts for about 60% of total NO_x emissions. (See Figure 5).

Natural sources include lightning and soil bacteria.

7.5 Method of Monitoring

Monitoring for oxides of nitrogen compounds is based on the principle of chemiluminescence involving a gas phase reaction of NO with ozone. For NO_2, the sample stream is passed through a catalytic converter where NO_2 is reduced to NO.

7.6 Locations of Monitors

The Appendix provides a description of the provincial NO_2 network (Table A-1).

NO_2 monitoring was carried out at 36 locations in 1991.

7.7 Monitoring Results

The distribution by percentile of the hourly data, the annual average, and the maximum one-hour and 24-hour values are provided in the Appendix (Tables A-12). Also given are the number of exceedances of the NO_2 AQC (see Section 7.3).

The lowest levels measured in the province were at Long Point (22901) in west central Ontario and Cornwall (56051) in southeastern Ontario where the arithmetic annual mean was 0.006 ppm. The highest annual mean (0.034 ppm) and the maximum 1-hour concentration (0.19 ppm) were measured in Toronto at the Mission site (31049).

There were no exceedances of the 1-hour AQC (0.20 ppm); however, the 24-hour AQC (0.10 ppm) was exceeded at the North York West site on one occasion during 1991. (See Table 1).

NO

NITRIC OXIDE

8.1 Characteristics

NO is a colourless and odourless gas which oxidizes to NO_2 in the presence of hydrocarbons and sunlight.

8.2 Effects

No known direct effects on health or vegetation at ambient levels.

8.3 Ontario Criteria

None

8.4 Sources

Same as for NO_2

8.5 Method of Monitoring

Same as for NO_2

8.6 Locations of Monitoring

Same as for NO_2

8.7 Monitoring Results

Parkhill (15013), a rural location in southwestern Ontario, recorded the lowest annual mean (0.001) while the Mission site (31049) in Toronto recorded the highest (0.057). (See Appendix Table A-13 for the data summaries).

NO_X

TOTAL NITROGEN OXIDES

NO_x is assumed to be the sum of NO_2 and NO concentrations in the atmosphere (in parts per million). NO_x contributes to haze and visibility reduction and is also known to cause deterioration and fading of certain fabrics and damage to vegetation. Depending on concentration and extent of exposure, plants may suffer leaf lesions and reduced crop yield. Sensitivity of plants to nitrogen oxides depends on a variety of factors including species, time of day, amount of light, stage of maturity and the presence or absence of other air pollutants such as SO_2 and ozone. (See Appendix Table A-14 for the data summaries.)

O_3

OZONE

10.1 Characteristics

Ozone is a colourless gas and a major component of photochemical oxidant compounds formed as the result of chemical reactions between nitrogen oxides and reactive hydrocarbons in the presence of sunlight. Two characteristics of ozone and oxidant exposures should be sited: (1) ozone itself is a primary cause of most of the health effects reported in toxicological and experimental human studies and the evidence for attributing many health effects to this substance alone is compelling, and (2) the complexity of atmospheric photochemical substances is known to produce health effects, some of which are attributable to pure ozone but may be caused by other photochemical substances in combination with ozone.

10.2 Effects

1 hour average

less than 50 ppb - no known effects

80 ppb - injurious to many species of vegetation

120 ppb decreasing performance by athletes exercising heavily

200 ppb - decrease in lung function in exercising subjects, eye irritation

10.3 Ontario Criteria

80 ppb (1-hour)

10.4 Sources

Ozone is produced by photochemical reactions and is not directly emitted into the atmosphere in significant amounts. Since it is formed downwind of nitrogen oxide and hydrocarbon sources and is capable of travelling long distances through the atmosphere, ozone is a manifestation of the long range transport of air pollution and a component of smog. Its formation and transport are dependent on meteorological factors. Warm temperatures are critical and elevated concentrations generally occur from May to September between noon and early evening. Ozone can also be formed naturally in the atmosphere by electrical discharge and in the stratosphere by photochemical reactions. The former process is not capable of producing significant urban concentrations of this pollutant; however, there is some belief that the incursion of ozone from the stratosphere can contribute significantly to elevated ground level concentrations of ozone under certain meteorological conditions. While the naturally occurring ozone in the stratosphere is beneficial to life by shielding the earth from harmful ultra-violet (U.V.) radiation given off by the sun, high concentrations of ozone at ground level are a major health and environmental concern.

10.5 Method of Monitoring

Chemiluminescence emission spectroscopy and U.V. absorption photometry methods are used to monitor for ozone.

In the first method, an air sample reacts with ethylene to emit visible light (chemiluminescence) of intensity directly proportional to the ozone concentration. In the second method, ozone absorption of U.V. light changes the intensity of the U.V. light beam, which is attenuated in proportion to the concentration of the ozone.

10.6 Location of Monitors

The Appendix provides a description of the provincial O_3 network (Table A-1).

Ozone monitoring was carried out at 48 locations in 1991.

10.7 Monitoring Results

The distribution by percentile of the hourly data, the mean, and the maximum one-hour and 24-hour values are provided in the Appendix (Table A-15). Also given are the number of exceedances of the ozone AQC (see Section 10.3).

The lowest levels measured in the province were at the Science Centre (34002) in North York where the annual mean was 14.7 ppb.

The highest annual mean concentration (34.2 ppb) and the maximum 1-hour averaged concentration (156 ppb) were measured at Tiverton (18007) on the eastern shore of Lake Huron. The 1-hour criterion was exceeded at 44 out of 48 ozone stations (92%) during 1991. The greatest number of exceedances (223) occurred at the CN Tower (31190) where the height of the monitor is 444 metres above the ground. The greatest number of 1-hour exceedances (218) at ground level occurred at Long Point a rural location in west central Ontario. Concentrations aloft are generally higher than those at ground level and during the night they are decoupled from the ground by the nocturnal inversion. (See Table 1).

Table 1: Highlights of the Continuous Monitoring Network 1991

	SO_2	SP	TRS	CO	THC	NO_2	NO	O_3
Lowest Mean Location	THUNDER BAY (63200)	SEVERAL (31190)	TIVERTON (18007)	SARNIA (14064) NORTH BAY (75010)	MISSISSAUGA (46117)	CORNWALL (56051) LONG POINT (22901)	PARKHILL (15013)	NORTH YORK (34002)
Concentration	0.0 ppm	0.17 UNIT	0.0 ppb	0.2 ppm	1.62 ppm	0.006 ppm	0.001 ppm	14.7 ppb
Highest Mean Location	HAMILTON (29102) COPPER CLIFF (77218)	TORONTO (31049)	TERRACE BAY (63093)	TORONTO (31049)	ETOBICOKE (35033)	TORONTO (31049)	TORONTO (31049)	TIVERTON (18007)
Concentration	0.014 ppm	0.61 UNIT	4.4 ppb	2.1 ppm	2.28 ppm	0.034 ppm	0.057 ppm	34.2 ppb
Most Criterion Exceedances - 1 hr Location Number	COPPER CLIFF (77218) 64	N/A	TERRACE BAY (63093) 379*	- 0	N/A	- 0	N/A	TORONTO (31190) 223
Most Criterion Exceedances - 24 hr Location Number	BALMERTOWN (61014) 2	TORONTO (31049) 35	N/A	N/A	N/A	NORTH YORK W (34020) 1	N/A	N/A
N0. Of Stations Exceeding 1 Hr AQC Number	16	N/A	24	0	N/A	0	N/A	44
No. Of Stations Exceeding 24 Hr AQC Number	6	21	N/A	N/A	N/A	1	N/A	N/A
Highest Measured Value - 1hr Location	SUDBURY (77096)	TORONTO (31049) WINDSOR (12016)	TERRACE BAY (63093)	TORONTO (31049)	OAKVILLE (44015)	TORONTO (31049)	YORK (36030)	TIVERTON (18007)
Concentration	1.25 ppm	4.7 UNIT	236 ppb	24.0 ppm	20.0 ppm	0.19 ppm	0.72 ppm	156 ppb
Total Number Of Stations	70	44	32	28	7	36	36	48

* Exceedances of pulp mill criterion of 27 ppb for 1-hour.
Figure in brackets is station number.

Section C - Air Quality Index

11.1 Characteristics

The Air Quality Index (AQI) is a real-time information system that provides the public with an indication of air quality at 34 sites in 27 major cities across Ontario. The system has been in operation since June 1988. The AQI is derived from calculations involving pollutant concentrations which have evidence of adverse effects on the environment. These pollutants are sulphur dioxide, ozone, nitrogen dioxide, total reduced sulphur compounds, carbon monoxide and suspended particles. In addition, the Air Pollution Index (API) (Section 12.0) is also included as an AQI sub-index along with the eight-hour average concentration of CO. It should be noted that not all parameters are measured at all AQI sites. The AQI is provided to the public eight times daily and it is increased to hourly releases when the index reaches 32, the level at which air quality is described as moderate.

11.2 Effect

The AQI sub-index is calculated on a hourly basis for each pollutant. The sub-index increases as the air quality deteriorates. The index values, the corresponding categories and the health and environmental effects are given in Table 2. The highest sub-index at the given time becomes the AQI.

If the index value reaches 50-99, the air quality may have adverse effects on the most sensitive of the human or animal population, or may cause significant damage to vegetation, property, or aesthetic value. An AQI value of 100 or greater may cause adverse effects to the health of a large sector of the exposed population.

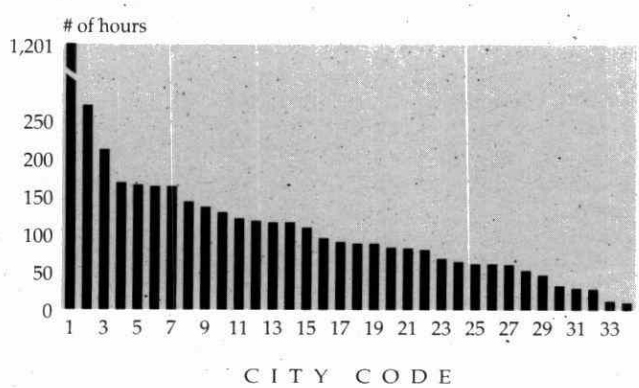
11.3 Operation of the System

In 1991, there were 34 AQI monitoring sites in Ontario. The larger cities have more than one AQI station (See Map 3 in Appendix). The cities are selected according to population and previous air quality history. The data from the 34 AQI stations are accessed on a real-time basis by the computer center at the Air Resources Branch. The computed indices are released to the public and the news media 8 times daily. In addition, AQI forecasts based on the meteorological conditions are issued four times daily. In the event that one of the AQI stations has an index greater than or equal to 32, the AQI information will be released hourly until it drops below 32. When the AQI is 50 or greater the Medical Officer(s) of Health for the affected region is informed.

11.4 Air Quality Index Levels (1991)

The frequency distribution of the hourly AQI, according to descriptive category, and according to the pollutant responsible for AQI $\geq$ 32, is shown for the thirty-four AQI monitoring locations across Ontario in Table 3. From this table, it is evident that at the majority of sites, ozone and suspended particles were the most frequent causes of elevated index readings. Total reduced sulphur compounds were the most frequent cause of high indices in Cornwall (56051), Fort Frances (62030) and Sault Ste Marie (71068). The API was elevated only at one site, Hamilton Downtown (29000). Very poor air quality was not reported at any of the AQI sites in 1991.

Figure 6:
Number of Hours of Moderate/Poor Air Quality at AQI Sites in Ontario 1991



1. Fort Frances
2. Windsor College
3. Cornwall
4. York
5. Burlington
6. Haminton West
7. Hamilton East
8. Niagara Falls
9. Guelph
10. North York West
11. East York
12. Etobicoke South
13. Etobicoke West
14. Toronto West
15. Sarnia
16. Oakville
17. Hamilton-Mountain
18. Oshawa
19. North York Central
20. Hamilton-Downtown
21. Windsor University
22. Kitchener
23. Kingston
24. Scarborough
25. Sault Ste Marie
26. Mississauga
27. London
28. St. Catharines
29. North Bay
30. Ottawa
31. Toronto-Downtown
32. Sudbury
33. Thunder Bay
34. Waterloo

Table 2: Air Quality Index Pollutants and Their Impact

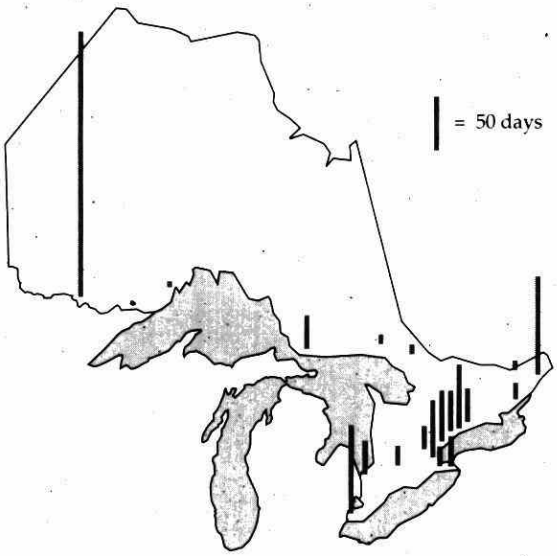
INDEX	CATEGORY	CARBON MONOXIDE CO	NITROGEN DIOXIDE NO_2	OZONE O_3	SULPHUR DIOXIDE SO_2	SUSPENDED PARTICLES SP	SO_2 + SP (AS MEASURED BY THE API)	TOTAL REDUCED SULPHUR TRS
100-over	Very poor	Increasing cardiovascular symptoms in non smokers with heart disease some visual impairment	Increasing sensitivity of patients with asthma and bronchitis	Light exercise produces respiratory effects in patients with chronic pulmonary disease	Increasing sensitivity in patients with asthma and bronchitis	Increasing sensitivity in patients with asthma and bronchitis	Significant respiratory effects in patients with asthma and bronchitis	Sensitive individuals may suffer nausea and headaches due to severe odour
50-99	Poor	Increased cardiovascular symptoms in smokers with heart disease	Odour and discoloration. Some increase in bronchial reactivity in asthmatics	Decreasing performance by athletes exercising heavily	Odourous increasing vegetation damage	Visibility decreased soiling evident	Increased symptoms in patients with chronic respiratory disease	Extremely odourous
32-49	Moderate	Blood chemistry but no detectable impairment	Odourous	Injurious to many vegetation species eg. white beans tomatoes etc.	Injurious to some species of vegetation	Some decrease in visibility	Injurious to vegetation to sulphur dioxide	Odourous
16-31	Good	No effects	Slight odour	Injurious to some vegetation species in combination with SO_2 (4 hrs)	Injurious to some vegetation species in combination with ozone (4 hrs)	No effects	No effects	Slight odour
0-15	Very good	No effects	No effects	No effects	No effects	No effects	No effects	No effects

Table 3: Air Quality Index Summary (1991)

Stn ID	CITY NAME	NUMBER OF HOURS AQI IN RANGE					# OF HOURS POLLUTANT RESPONSIBLE FOR AQI>31						
		V-GOOD 0-15	GOOD 16-31	MOD 32-49	POOR 50-99	V-POOR 100+	SO_2	SP	0_3	TRS	CO	API	NO_2
44008	Burlington	7039	1508	159	4	0	0	40	123	X	0	0	0
56051	Cornwall	7439	993	164	46	0	1	3	19	187	0	0	0
32010	East York	7011	1529	117	2	0	0	98	21	X	0	0	0
35003	Etobicoke West	7638	1008	114	0	0	0	29	85	X	0	0	0
35033	Etobicoke South	7012	1522	115	1	0	0	65	51	X	0	0	0
62030	Fort Frances *	6882	632	950	251	0	X	X	X	1201	X	X	X
28028	Guelph	7860	761	134	0	0	0	0	134	X	X	0	X
29000	Hamilton Downtown	7160	1519	81	0	0	0	22	37	10	0	12	0
29105	Hamilton East	7557	1042	160	1	0	0	5	156	0	X	0	X
29114	Hamilton Mountain	7726	923	87	1	0	0	1	85	2	X	0	0
29118	Hamilton West	6897	1605	159	2	0	0	51	79	31	X	0	0
26060	Kitchener	7780	902	78	0	0	0	1	77	X	0	0	0
52020	Kingston +	7208	474	66	0	0	X	X	66	X	X	X	X
15001	London	7886	816	58	0	0	0	5	53	X	0	0	0
46110	Mississauga	7803	851	59	0	0	0	28	31	X	0	0	0
27056	Niagara Falls	7772	808	141	0	0	0	0	141	X	X	0	X
34020	N. York Central	7679	995	83	3	0	0	14	72	X	0	0	0
34025	N. York West	6610	1895	127	0	0	0	98	29	X	0	0	0
75010	North Bay	7991	563	44	0	0	0	5	39	X	0	0	0
44015	Oakville	7267	1400	90	3	0	0	40	44	9	0	0	0
45025	Oshawa	7705	968	85	1	0	0	19	67	X	0	0	0
51001	Ottawa	8199	464	30	0	0	0	9	21	X	0	0	0
14064	Sarnia	7704	948	102	5	0	0	1	98	8	0	0	0
71068	Sault Ste Marie	7759	663	58	1	0	0	20	0	39	X	0	0
33003	Scarborough	7869	814	61	1	0	0	6	56	X	0	0	0
27067	St. Catharines	7833	877	50	0	0	0	6	44	X	0	0	0
77203	Sudbury	8206	447	22	4	0	7	2	16	1	0	0	0
63200	Thunder Bay	8615	134	10	0	0	0	3	0	7	0	0	0
31103	Toronto Downtown	7712	1021	27	0	0	0	18	9	X	0	0	0
31120	Toronto West	7511	1135	111	3	0	0	20	94	X	0	0	0
26045	Waterloo	8350	401	8	0	0	0	0	8	X	X	0	X
12008	Windsor University	7969	711	80	0	0	0	8	72	X	0	0	0
12016	Windsor College	7173	1319	260	8	0	0	45	168	55	0	0	0
36030	York	7072	1522	163	3	0	0	96	63	X	0	0	0

* Fort Frances - TRS Only Pollutant Monitored
\+ Kingston - O_3 Only Pollutant Monitored
X Pollutant Not Monitored

Figure 7:
Number of Days With Moderate/Poor Air Quality in Ontario 1991



The total number of hours of moderate/poor air quality (see Figure 6) and the number of days on which the AQI was in the moderate/poor range for at least one hour at each AQI site is shown in Table 4. From this table it should be noted that during 1991 Fort Frances (62030) recorded at least one hour of moderate/poor air quality on approximately 58% of the monitoring days as compared to Cornwall (56051) at 24%, Windsor College (12016) at 21%, York (36030) at 16%, Hamilton West (29118) at 14% and Waterloo (26045) which recoreded the lowest percentage of days of moderate/poor air quality at less than 2%. Figure 7 shows the number of days with moderate/poor air quality at AQI sites across the province.

12.0 AIR POLLUTION INDEX (API)

12.1 Characteristics

The API continues to be the basis of an alert and control system to warn of deteriorating air quality and is derived from 24-hour running averages of SO_2 and SP. Research studies have linked respiratory illness to elevated concentrations of SO_2 and particulates.

12.2 Legislation

Regulation 346 under the the Ontario Environmental Protection Act (1971) authorizes the Minister of the Environment to order any point source not essential to public health or safety to curtail or cease its operations when air pollution levels occur which may be injurious to health.

Table 4: Number of Hours/Days of Moderate/Poor Air Quality at AQI Sites (1991)

Station ID	City Name	Number of Hours AQI > 31	Number of Days at Least 1 hour - AQI > 31
44008	Burlington	163	46
56051	Cornwall	210	87
32010	East York	119	38
35003	Etobicoke West	114	35
35033	Etobicoke South	116	40
62030	Fort Frances *	1201	211
28028	Guelph	134	24
9000	Hamilton Downtown	81	31
29105	Hamilton East	161	28
29114	Hamilton Mountain	88	23
29118	Hamilton West	161	51
26060	Kitchener	78	20
52020	Kingston +	66	14
15001	London	58	19
46110	Mississauga	59	24
27056	Niagara Falls	141	28
34020	N. York Central	86	27
34025	N. York West	127	47
75010	North Bay	44	10
44015	Oakville	93	35
45025	Oshawa	86	29
51001	Ottawa	30	9
14064	Sarnia	107	28
71068	Sault Ste Marie	59	31
33003	Scarborough	62	20
27067	St. Catharines	50	18
77203	Sudbury	26	10
63200	Thunder Bay	10	7
31103	Toronto Downtown	27	14
31120	Toronto West	114	32
26045	Waterloo	8	6
12008	Windsor University	80	24
12016	Windsor College	268	75
36030	York	166	58

* Fort Frances - TRS Only Pollutant Monitored
\+ Kingston - 0_3 Only Pollutant Monitored

12.3 Operation of the System

The API is computed each hour based on the past 24 hourly values for SO_2 and SP. If the index reaches a value of 32 and if the Duty Meteorologist predicts a continuation of adverse atmospheric conditions for at least six hours, an Air Pollution Advisory is issued. Owners of significant sources of pollution are advised to prepare for possible curtailment of operations.

If the index reaches 50, and if at least six hours of adverse atmospheric conditions are forecast, owners of major sources may be ordered to curtail operations. This is the First Alert Level.

Table 5: Number of Occasions API ≥ 32 at Sites Across Ontario (1988-1991)

Stations	1988	1989	1990	1991
Toronto Downtown				
Hamilton Downtown	1 (43)	3 (37)	2 (42)	1 (34)
Sudbury			2 (42)	
Windsor (12008)				
Windsor (12016)		1 (32)		
Niagara Falls				
Sarnia				
St. Catharines				
Toronto West		1 (33)		
East York		1 (34)		
Scarborough		1 (34)		
North York Central				
North York West		1 (38)	1 (32)	
Etobicoke West	1 (33)			
Etobicoke South		2 (33)		
York	2 (38)	1 (33)		
Burlington		1 (34)	2 (34)	
Oakville				
Oshawa				
Mississauga		1 (35)		
London		1 (32)		
Kitchener				
Waterloo				
Guelph				
Hamilton East				
Hamilton Mountain			1 (38)	
Hamilton West			1 (32)	
Sault Ste Marie				
North Bay				
Ottawa				
Cornwall				
Thunder Bay				

Note: Figure in Brackets is Maximum API Recorded

A Second Alert is issued at an API of 75, and further curtailment may be ordered.

The Air Pollution Episode Threshold Level occurs at an API of 100. If atmospheric conditions are not expected to improve for at least six hours, owners of all sources not essential to public health or safety may be ordered to cease operations.

12.4 Air Pollution Index Levels (1988-1991)

A history of the Air Pollution Index levels over the last 4 years of its operation is provided in Table 5.

13.0 Lambton Industrial Meteorological Alert (LIMA)

The Lambton Industrial Meteorological Alert system (LIMA) is part of the Environmental Protection Act - Reg. 350. The application of this alert is limited to that part of the county of Lambton bounded by Lake Huron, the St. Clair River, the King's Highway known as No. 80, the roadway known as Moore Township Road 31 and its continuation through that part of the King's Highway known as No. 40 and Lambton County road 27, which includes the city of Sarnia.

Table 6: Lambton Industrial Meteorological Alert Summary (1982-1991)

Year	Alerts Called	Average Duration (Hours)
1982	13	14
1983	5	18
1984	7	15
1985	3	16
1986	8	14
1987	0	-
1988	5	24
1989	3	12
1990	9	16
1991	8	23

The Minister may declare an Alert when the 24-hour running average sulphur dioxide concentration at any station in the Lambton Industrial Meteorological Alert system reaches 0.07 ppm and meteorological forecasts indicate a continuation for six hours or more of weather conditions conducive to elevated SO_2 concentrations.

Two monitoring sites are located in Sarnia (Front Street and Centennial Park), one in Corunna (River Bend) and one in Michigan (Port Huron).

During 1991 the alert was issued on eight occasions. The longest duration of the alert was 62 hours lasting from 1600 EST on October 23, 1991 to 0600 EST on October 26, 1991. The maximum 24-hour running average SO_2 concentration during this episode reached 0.09 ppm and was recorded at the Centennial Park monitoring site. The highest 24-hour running average SO_2 concentration recorded during 1991 was 0.12 ppm and was recorded at Front Street on December 20, 1991.

On two other occasions the LIMA reached 0.07 ppm but the alert was not issued since the meteorological conditions were not conducive for the build up of SO_2 concentrations.

Three LIMA alerts for Centennial Park were simultaneously issued with three of the eight alerts issued for Front Street. One alert was issued for Port Huron on March 6, 1991 at 0600 EST and lasted for 12 hours. The highest 24-hour running average SO_2 concentration recorded during this period was 0.09 ppm.

The number of LIMA alerts called over the past 10 years is displayed in Table 6.

Section D - Pollutants Measured by High Volume Sampler Monitoring (Daily Data)

TSP

TOTAL SUSPENDED PARTICULATES

14.1 Characteristics

Total suspended particulate is a generic term for airborne particles including smoke, fume, dust, fly ash and pollen. Composition varies with place and season but normally includes soil particulates, organic matter, sulphur and nitrogen compounds and metals such as lead. Size range is approximately 0.1 to 100 microns (diameter).

14.2 Health Effects

The greatest impact on health is from particles less than 10 microns in diameter which can penetrate deep into the lungs and contribute to respiratory disease (see Section 15.1). More serious health effects may be associated with suspended particulate matter which contains a toxic particulate component or which has absorbed a gaseous pollutant on the surface of the particles. Corrosion, soiling, damage to vegetation and visibility reduction are additional effects.

14.3 Ontario Criteria

120 $\mu g/m^3$ (24-hours)
60 $\mu g/m^3$ (1-year - geometric mean)

14.4 Sources

Natural sources of TSP include wind-blown soil, forest fires and plant pollen. Anthropogenic sources include combustion, incineration, construction, mining, metals smelting and processing, grinding processes, agricultural activity and transportation (See Figure 6).

14.5 Method of Monitoring

TSP is measured by an instrument called a Hi-vol sampler. Air is drawn through a filter at the rate of approximately 1.4 cubic metres per minute (m^3/min). The (daily) mass concentration of total suspended particulate matter is computed gravimetrically from the mass of collected particles and the volume of air sampled.

14.6 Location and Frequency of Monitoring

The monitoring locations and the frequency of sampling at each location are indicated in the Appendix (Table A-2).

TSP was measured at 125 locations in 1991.

14.7 Monitoring Results

The distribution by percentile, the maximum and the geometric mean are given in the Appendix (Table A-16). Also given are the number of exceedances of the 24-hour and 1-year criteria. The lowest levels measured in the province were at Dorset (49010) where the annual geometric mean was 13 $\mu g/m^3$.

The highest annual geometric mean (93 $\mu g/m^3$) was recorded at Niagara Falls (27055) near an abrasives manufacturing plant while the maximum daily value (720 $\mu g/m^3$) was measured near the Canada Metal Plant in Toronto (31065). The greatest percentage of exceedances (38) of the 24-hour criterion occurred at the Stanley Avenue monitor (27055) in Niagara Falls.

There was a total of 76 stations (60%) which exceeded the 24-hour criterion and 15 which exceeded the one-year criterion. (See Table 7b).

IP

INHALABLE PARTICULATE

15.1 Characteristics

The term "PM-10 fraction" has been given to the fraction of the total suspended particulate which has a diameter of 10 μm or less. This

Figure 8:
Ontario Particulate Emissions by Sectors
(Annual Emission 200 kT)

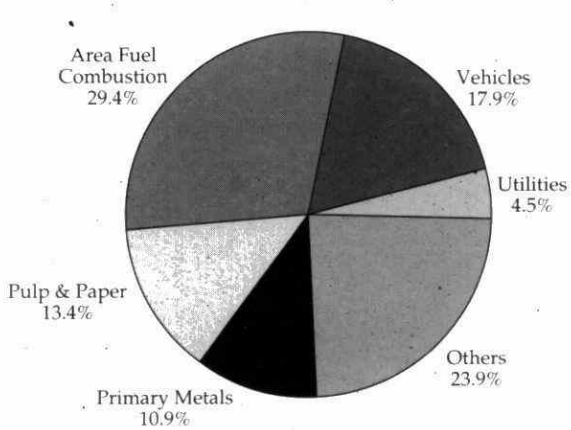


Table 7a: Comparison of Inhalable Particulate (IP) Versus Total Suspended Particulate (TSP) 1991

City	Station Location	N	Mean IP	Mean TSP	Max IP	Max TSP	% IP OF TSP	IP = A + B (TSP)	r
Windsor	Wright/Water	52	25	53	60	105	47	IP = .46 + .50 (TSP)	.79
Windsor	467 University Avenue	60	25	51	69	137	49	IP = -2.8 + .57 (TSP)	.91
London	801 Commissioners	46	19	52	55	144	36	IP = 1.6 + .57 (TSP)	.85
Thorold	185 Queen St.S	54	32	69	100	168	46	IP = -6.2 + .59 (TSP)	.86
Hamilton	Elgin/Kelley	52	26	61	70	164	43	IP = 6.2 + .34 (TSP)	.72
Hamilton	Beach Blvd.	45	29	70	100	211	41	IP = .6 + .42 (TSP)	.90
Hamilton	Gertrude/Depew	52	33	67	86	166	49	IP = -6.1 + .59 (TSP)	.92
Toronto	Bay/Grosvenor	52	25	67	120	379	37	IP = 8.1 + .29 (TSP)	.90
Etobicoke	Evans/Arnold	99	26	65	81	170	40	IP = -.1 + .47 (TSP)	.84
Scarborough	Kennedy/Lawrence	59	24	54	75	146	44	IP = -3.5 + .48 (TSP)	.90
Thunder Bay	615 James St.S	55	17	38	46	112	45	IP = 3.8 + .36 (TSP)	.89
S.S. Marie	Bonney St.	51	29	60	160	393	48	IP = 7.0 + .38 (TSP)	.93
S.S. Marie	Wm. Merrifield	57	19	26	65	111	73	IP = 6.8 + .40 (TSP)	.86

N = Number of data points
Units are in $\mu g/m^3$

r = Linear correlation coefficient
Mean - Geometric mean

IP is measured by PM-10 sampler

has been determined to be the particle size which is most likely to be inhaled and deposited into the thoracic region of the lung.

15.2 Effects

IP effects are on pulmonary function, aggravation of existing pulmonary and cardiovascular disease, mucociliary clearance and other host mechanisms. Corrosion, soiling, damage to vegetation and visibility reduction are additional effects.

15.3 Ontario Criteria

None at present.

15.4 Sources

Same as for TSP.

15.5 Method of Monitoring

IP is monitored by a modified Hi-vol sampler outfitted with a size selective inlet to restrict particle size to less than 10 µm. The daily mass of the inhalable particulate is computed from the mass of the collected particles and the volume of air sampled. Quartz fibre filters are used as the filter medium for collection.

15.6 Location and Frequency of Monitoring

PM-10 monitoring locations are shown in the Appendix, Map 8. All sites operated on a one in 6-day sampling schedule. Monitoring for PM-10 completed its first full year of measurements at five sites in 1990. During 1991, inhalable particulate was measured at 15 locations.

15.7 Monitoring Results

The distribution by percentile, the maximum and the geometric mean are given in the Appendix, (Table A-17), for inhalable particulate as well as for lead and selected inhalable trace metals such as chromium, vanadium, copper, iron, manganese and nickel. There are presently no criteria for these trace metals in the inhalable particulate size fraction.

For the inhalable particulate, the highest annual geometric mean (33 $\mu g/m^3$) was recorded at the Hamilton monitor (29313) while the maximum daily value (160 $\mu g/m^3$) was recorded at the Bonney Street monitor (71342) in Sault Ste Marie (See Table 7b).

A comparison of inhalable particulate versus TSP was done for all available data collected during 1991. Table 7a summarizes the data as to the number of samples, the mean and maximum recorded values of IP and TSP, the percentage IP of the TSP loading, the linear equation expressing IP in terms of TSP and the corresponding r value. IP varies from 36% of the TSP loading at the London site to 73% of the total loading at the Merrifield monitor in Sault Ste. Marie.

Pb

LEAD IN TOTAL SUSPENDED PARTICULATE

16.1 Characteristics

Lead is a silver-bluish, white, soft metal with a gram molecular weight of 207.20. It is a stable compound which persists and accumulates both in the environment and in the human body. Lead enters the body primarily through ingestion and inhalation with consequent absorption into the blood stream and distribution to all body tissues.

16.2 Effects

Clinical, epidemiological and toxicological studies have demonstrated exposure to lead adversely affects human health. Lead can degrade renal function, impair haemoglobin synthesis, and alter the nervous system.

16.3 Ontario Criteria

5.0 $\mu g/m^3$ (24-hours)
2.0 $\mu g/m^3$ (30-day - geometric mean)

16.4 Sources

Lead sources include combustion of gasoline containing lead additives, secondary smelting of lead, battery manufacturing, metal fabrication, some paint and glass manufacturing, production of iron, steel, copper and nickel. Lead emissions fell significantly after 1975 with the introduction of lead-free gasoline.

16.5 Method of Monitoring

The lead concentration on high volume filters is analyzed by either X-Ray fluorescence or atomic absorption.

16.6 Location and Frequency of Monitoring

The monitoring locations and sampling frequency for each location are indicated in the Appendix (Table A-2). Lead was measured at 69 locations in 1991.

16.7 Monitoring Results

The distribution by percentile, the maximum, the arithmetic mean and the geometric mean are given in the Appendix (Table A-18).

Also given are the number of exceedances of the 24-hour criterion.

The greatest percentage of exceedances of the 24-hour criterion occurred at the Eastern Avenue monitor (31065) in Toronto. This monitoring site is located in the vicinity of a lead processing plant.

The highest annual geometric mean (0.58 $\mu g/m^3$) was recorded at station 46041 in Mississauga while the maximum 24-hour concentration (13.76 $\mu g/m^3$) occurred at station 31065 in Toronto.

There were a total of 5 stations (all near lead processing plants) which exceeded the daily criterion at least once (see Table 7b).

TRACE METALS

CADMIUM, CHROMIUM, IRON, MANGANESE, NICKEL, VANADIUM, COBALT, COPPER

17.1 Characteristics

Name	Symbol	Properties	Molecular Weight
Cadmium	Cd	silver white, hexagonal	112.41
Chromium	Cr	steel grey, cubic	52.00
Iron	Fe	silver, cubic	58.85
Manganese	Mn	grey-pink, cubic	54.94
Nickel	Ni	silver, cubic	58.60
Vanadium	V	light grey, cubic	50.94
Cobalt	Co	Silver, grey, cubic	58.93
Copper	Cu	red, cubic	63.55

17.2 Effects

The depth of penetration into the respiratory system (and consequently risk to health) increases as particle size decreases. Of the heavy metals, cadmium, chromium, vanadium and manganese probably pose the greatest risk to human health. Soiling and damage to vegetation are additional effects.

17.3 Ontario Criteria

	24 Hour Criterion	Limiting Effects Based On
Cadmium	2 $\mu g/m^3$	Health
Chromium	1.5 $\mu g/m^3$	Health
Manganese	2.5 $\mu g/m^3$	Health
Nickel	2 $\mu g/m^3$	Vegetation
Vanadium	2 $\mu g/m^3$	Health
Copper	50 $\mu g/m^3$	Health

17.4 Sources

See Section 14.4.

17.5 Method of Monitoring

The collection method is by Hi-vol sampler (see Section 14.5). Following determination of TSP, a portion is cut from the exposed filter and ashed to destroy carbonaceous matter. The ashed sample is then digested in acid, and analyzed by atomic absorption spectrophotometry. The mass concentration of each metal in ambient air is calculated from the mass of each metal in TSP and the volume of air sampled, and expressed in $\mu g/m^3$.

17.6 Location and Frequency of Sampling

The monitoring locations and the sampling frequency for each location are indicated in the Appendix (Table A-2).

Metals were measured at 42 to 49 stations depending on the element.

17.7 Monitoring Results

The distribution by percentile of the daily data, the maximum, the arithmetic mean, the geometric mean, and the number of exceedances of the daily criterion are provided in the Appendix for cadmium, chromium, iron, manganese, nickel, vanadium, cobalt and copper (See Table A-19 through A-25). Table A-26 shows the maximum monitored levels for all the trace metals listed above. No table is provided for cobalt because a large percentage of the values were below the detection limit.

Table 7b provides the highlights of particulate monitoring for 1991. It shows that one exceedance of the air quality criteria for metals (exclusive of lead) occurred in 1991. The exceedance occurred at Port Colborne (27047) and nickel was the metal responsible. Such exceedances may be harmful to vegetation.

NO_3^-

NITRATE

18.1 Characteristics

Nitrogen oxide compounds are formed from atmospheric nitrogen and oxygen through high temperature combustion, photochemical reactions or bacterial action and may react with other compounds in the air to form nitrate (NO_3^-) or nitric acid (HNO_3).

18.2 Effects

Nitrate and nitric acid are involved in corrosion of materials, visibility degradation and acidic precipitation. They may also have an adverse effect on human health.

18.3 Ontario Criteria

None

18.4 Sources

Nitrate is primarily a secondary pollutant. Anthropogenic sources of nitrogen oxides or nitrates include all high temperature combustion processes, transportation, and fertilizer production and usage. Natural sources include lightning, biological decomposition and photochemical reactions.

18.5 Method of Monitoring

Nitrates are collected on glass fibre filters by a Hi-vol sampler and they are extracted by distilled water. This extract is reduced to nitrite followed by colourimetric analysis for determination of the mass concentration of atmospheric nitrate.

18.6 Location and Frequency of Monitoring

The monitoring locations and the length of the sampling cycle (in days) for each location are indicated in the Appendix (Table A-2).

Nitrate monitoring was carried out at 32 locations in 1991.

18.7 Monitoring Results

The distribution by percentile, the maximum, the arithmetic mean, and the geometric mean are given in the Appendix (Table A-27). Highlights of monitoring are summarized in Table 7b.

The highest annual geometric mean nitrate concentration (5.1 $\mu g/m^3$) occurred in Windsor (12015) and the highest concentration for a single day (21.6 $\mu g/m^3$) occurred in Nanticoke (22904).

SO_4^{2-}

SULPHATE

19.1 Characteristics

Sulphur dioxide is oxidized in the atmosphere to eventually form sulphate compounds. Intermediaries in the oxidation process such as H_2SO_3 and SO_3 rapidly combine with water vapour to form sulfuric acid aerosol. This type of process is dependent on atmospheric conditions.

19.2 Effects

Sulphate compounds have been linked to respiratory irritation and disease, corrosion of materials, reduction of visibility and the formation of acidic precipitation.

19.3 Ontario Criteria

None.

19.4 Sources

Sulphate is primarily a secondary pollutant. Anthropogenic sources of sulphur oxides include the burning of fuels containing sulphur (such as coal and oil), the smelting of sulphur-containing ores and the refining of petroleum. Natural sources include bacterial decomposition, volcanoes and forest fires.

19.5 Method of Monitoring

Sulphate is collected on glass fibre filters by a Hi-vol sampler and it is extracted by distilled water. This extract is analyzed colourimetrically and the mass concentration of sulphate is calculated. It has been found that artifact sulphates form on the glass fibre filters from ambient SO_2 and that reported sulphate concentrations are therefore artificially high. No attempt has been made to correct the data reported here.

19.6 **Location and Frequency of Monitoring**

The monitoring locations and the length of the sampling cycle (in days) for each location are indicated in the Appendix (Table A-2). Sulphate monitoring was carried out at 32 locations in 1991.

19.7 **Monitoring Results**

The distribution by percentile, the maximum, the arithmetic mean, and the geometric mean are given in the Appendix (Table A-28). Highlights of monitoring are summarized in Table 7b.

The highest annual geometric mean sulphate concentration (13.0 $\mu g/m^3$) was measured at Hamilton (29102) and the highest concentration (82.5 $\mu g/m^3$) for a single day occurred at Sault Ste Marie (71042).

Table 7b: Highlights of the Suspended Particulate (Hivol) Monitoring Network 1991

	TSP	IP	Pb	Cr	Fe	Mn	Ni	Cu	NO^-_3	SO_4^{2-}	V
Lowest Geom Mean											
Location	Dorset (49010)	Thunder Bay (63201)	Several	Several	Several	Mooretown (14031)	Hamilton (29017)	Several	S.S.Marie (71042) (71068)	Thunder Bay (63022)	Several
Concentration	13 $\mu g/m^3$	17 $\mu g/m^3$	0.00 $\mu g/m^3$	0.005 $\mu g/m^3$	0.2 $\mu g/m^3$	0.008 $\mu g/m^3$	0.004 $\mu g/m^3$	0.010 $\mu g/m^3$	0.8 $\mu g/m^3$	4.3 $\mu g/m^3$	0.005 $\mu g/m^3$
Highest Geom Mean											
Location	Niagara Falls (27055)	Hamilton (29313)	Mississauga (46041)	Hamilton (29011)	Windsor (12038)	Hamilton (29011)	Copper Cliff (77070)	Schreiber (63400)	Windsor (12015)	Hamilton (29102)	Sarnia (14064)
Concentration	93 $\mu g/m^3$	33 $\mu g/m^3$	0.58 $\mu g/m^3$	0.019 $\mu g/m^3$	4.9 $\mu g/m^3$	0.258 $\mu g/m^3$	0.121 $\mu g/m^3$	0.26 $\mu g/m^3$	5.1 $\mu g/m^3$	13.0 $\mu g/m^3$	0.010 $\mu g/m^3$
Percentage of Samples Above 24-Hr AQC	Niagara Falls	N/A	Toronto		N/A		Port Colborne		N/A	N/A	
Location	(27055)		(31065)				(27047)				
Value	38		3	0		0	2	0			0
No. Of Stations Exceeding 24-Hr AQC											
Number	76	N/A	5	0	N/A	0	1	0	N/A	N/A	0
No. Of Stations Exceeding 1-Yr AQC											
Number	15	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Highest Measured Value - 24-Hr	Toronto	S.S. Marie	Toronto	Hamilton	S.S.Marie	S.S. Marie	Port Colborne	Schreiber	Nanticoke	S.S. Marie	Sarnia
Location	(31065)	(71342)	(31065)	(29114)	(71042)	(71042)	(27047)	(63401)	(22904)	(71042)	(14064)
Concentration	720 $\mu g/m^3$	160 $\mu g/m^3$	13.76 $\mu g/m^3$	0.340 $\mu g/m^3$	68.3 $\mu g/m^3$	1.810 $\mu g/m^3$	4.510 $\mu g/m^3$	2.15 $\mu g/m^3$	21.6 $\mu g/m^3$	82.5 $\mu g/m^3$	0.140 $\mu g/m^3$
Total Number of Stations	125	15	69	42	49	45	45	46	32	32	42

Figure in brackets is station number

Section E - Pollutants Measured by Dustfall Jar and Fluoride Candle (Monthly Data)

TDF

TOTAL DUSTFALL

20.1 Characteristics

Total Dustfall is a measure of the amount of settleable particulate in the atmosphere. The larger, more visible fraction of the particulate matter will settle out more rapidly than the fine particulate. Composition varies with place and season but normally includes soil particulates, organic matter, sulphur and nitrogen compounds, metals and re-entrained road dust.

20.2 Effects

There are generally no health effects associated with total dustfall; however, adverse health effects may be associated with dustfall which contains a toxic component or which has absorbed a gaseous pollutant on the surface of the particles. Corrosion, soiling, damage to vegetation and visibility reduction are additional effects.

20.3 Ontario Criteria

7.0 $g/m^2/30$ days (30 days)
4.6 $g/m^2/30$ days (1-year arithmetic mean)

20.4 Sources

Same as TSP and SP (COH).

20.5 Method of Monitoring

Dustfall is collected by exposing an open top plastic jar for 30-days. The total amount of dustfall is determined by weighing the contents of the jar and expressing the results in $g/m^2/30$ days.

The settleable particulate collected in the dustfall jar can be separated into a soluble and insoluble fraction for further analysis. The insoluble portion can be examined using an optical microscope to determine the composition of the particulate. Total dustfall can be analyzed for metals and other compounds which are listed in Table A-3.

20.6 Location and Frequency of Monitoring

Dustfall was measured at 166 locations throughout the province in 1991. The monitoring locations are indicated in the Appendix (Table A-3).

20.7 Monitoring Results

The monthly values, the maximum, the geometric standard deviation and the arithmetic and geometric means are given in the Appendix (Table A-29).

The highest annual arithmetic mean (10.7 $g/m^2/30$ days) was recorded at the station (29036) in the heart of Hamilton's industrial area while the highest monthly value (53.3 $g/m^2/30$ days) was recorded at the Fort York monitor (31183) in Toronto.

There was a total of 101 stations (61%) which exceeded the monthly (30-day) criterion and 47 stations (28%) which exceeded the 1-year criterion.

FLR

FLUORIDATION RATE

21.1 Characteristics

Fluoridation rate is a measurement designed to indicate relative amounts of gaseous fluorides present over an extended period of time.

21.2 Effects

On vegetation

21.3 Ontario Criteria

40 $\mu g/100\ cm^2/30$ days - growing season:
(April 1 - October 31 for southern Ontario); (May 1 - September 30 for northern Ontario)
80 $\mu g/100\ cm^2/30$ days - (November 1 - March 31 for southern Ontario); (October 1 - April 30 for northern Ontario)

21.4 Sources

Anthropogenic sources include fossil fuel power plants, brick manufacturing plants, fertilizer plants, petroleum refineries and the steel industry.

21.5 Method of Monitoring

A lime impregnated filter paper is exposed to ambient air for 30-days and subsequently analyzed for fluoride content.

21.6 Location and Frequency of Monitoring

Fluoridation rate was measured at 72 locations in 1991. The monitoring locations are indicated in the Appendix (Table A-3).

21.7 Monitoring Results

The monthly values, the maximum, the standard deviation and the arithmetic and geometric means are given in the Appendix (Table A-30).

The highest annual arithmetic mean (415 $\mu g/100\ cm^2/30$ days) was recorded at Hamilton (29127) with the highest monthly value (1357 $\mu g/100\ cm^2/30$ days) also measured here. This station is immediately adjacent to a brick manufacturer.

During the growing season, 41 stations (57 percent) recorded exceedances of the monthly 30-day criterion.

Section F - Provincial Trends In Air Quality and Emissions

The ambient air quality trends presented in this section are based on direct measurements. These trends are supplemented with trends for annual province-wide emissions from the Ontario Emissions Inventory System (OEIS). Emissions are based on the amount and kinds of pollution being emitted by automobiles, factories, and other sources, and are derived from the best available engineering calculations for a given time period.

For SO_2, emission estimates are obtained mainly from mass balance calculations or computer calculation employing standard emission factors.

For CO, NO_x and volatile organic hydrocarbons (VOC), emission estimates for the dominant sector, i.e., gasoline and diesel-powered motor vehicles, were based upon vehicle mile tabulations and emission factors from the Mobile 4.0 model.

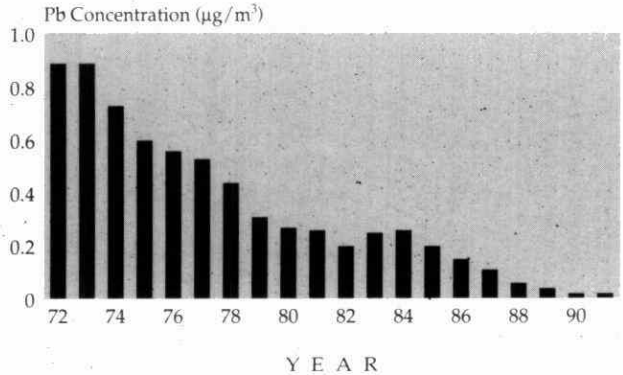
It should be noted, however that the methods currently in use worldwide to obtain emission information from the sources may have some uncertainty. Given this uncertainty in emission estimates, the trend information is more reliable for SO_2 than for the other pollutants.

Because of changes that have occurred in ambient monitoring measurement methodology and the change over time in the geographical distribution of monitors, it is difficult to provide ambient trends going back twenty years for all pollutants; yet, it is important not to lose sight of some of the earlier progress that was made in air pollution control in Ontario. The pollutants which can be displayed are SO_2, CO, TSP, Pb, THC and SP. Figures 9a to 9f show the 20-year trend in the composite average of annual means for SO_2, CO, TSP, Pb, THC and SP at monitoring sites which have operated continuously during the past twenty years. Over this 20-year period, Pb clearly shows the most impressive decrease of 99%. Significant decreases are also evident for SO_2 (75%), CO (75%) and TSP (49%). The THC and SP trends have remained relatively constant over the 20-year period. Figure (9g) shows the 17-year trend in NO_2 levels while Figure (9h) shows the 13-year trend in O_3 across Ontario. NO_2 levels have decreased by 17% over the 17-year period while O_3 has increased by the same amount over the 13-year period.

22.1 10-Year Trend in Sulphur Dioxide (SO_2)

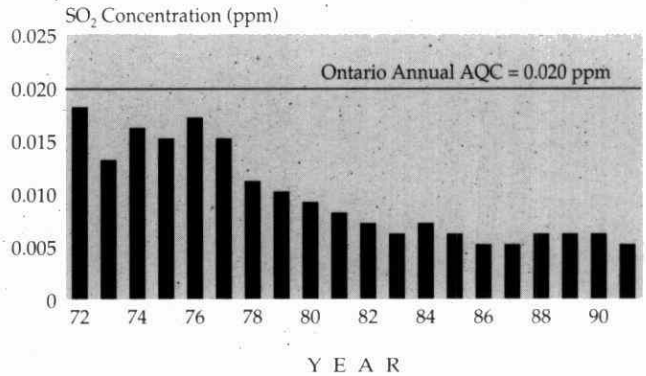
The 10-year trend in mean ambient SO_2, 1982 to 1991, is presented in Figure 10 and Table 8a for twenty-five sites which possess a continuous ten-year record. Annual mean ambient SO_2 levels have improved by about 33% over the 10-year period (75% over the 20-year period, see Figure 9b). The majority of monitors in Ontario's urban centres meet the provincial 1-hour objective (0.25 ppm). Of the sixteen stations which exceeded the provincial 1-hour SO_2 AQC in 1991, 12 were located in the Sudbury basin area. The Inco and Falconbridge smelting operations in the Sudbury area are

Figure 9a:
20-Year Trend for Pb in TSP



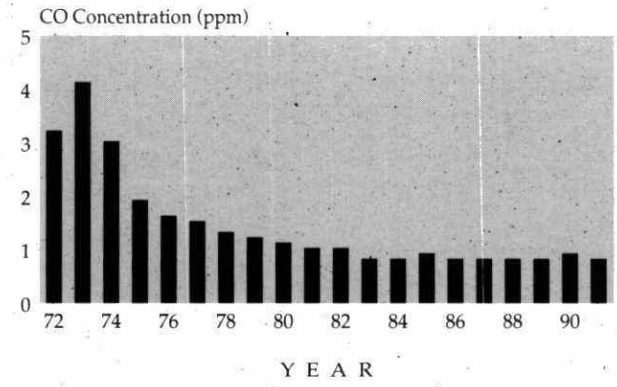
10 Sites operated over 20 years

Figure 9b:
20-Year Trend for SO_2



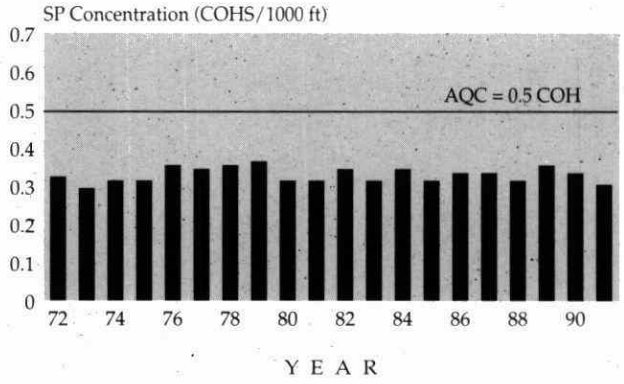
12 Sites operated over 20 years

Figure 9c: 20-Year Trend for CO



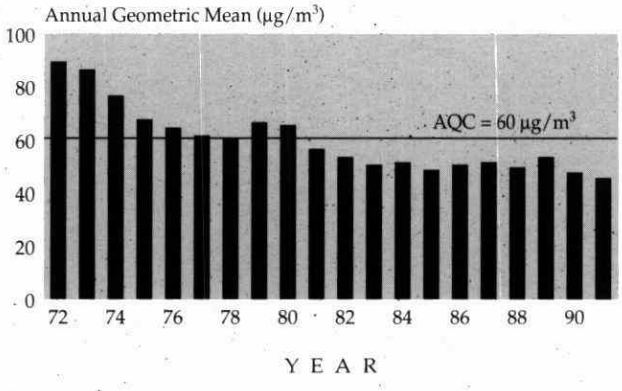
9 Sites operated over 20 years

Figure 9f: 20-Year Trend for SP



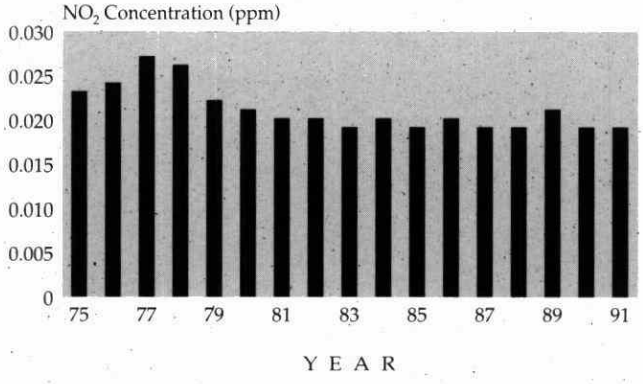
10 Sites operated over 20 years

Figure 9d: 20-Year Trend for TSP



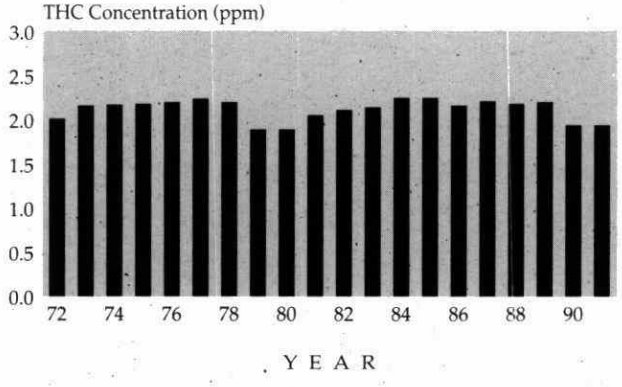
14 Sites operated over 20 years

Figure 9g: 17-Year Trend for NO_2



15 Sites operated over 17 years

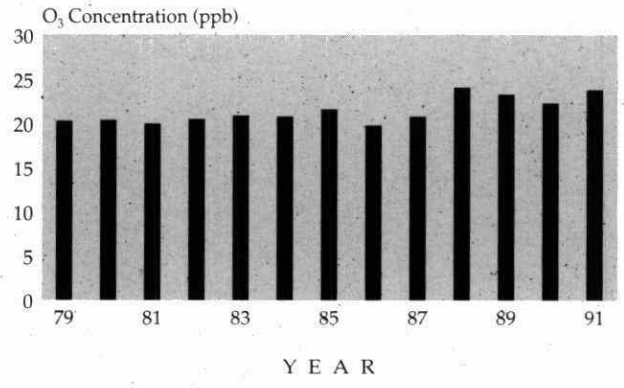
Figure 9e: 20-Year Trend for THC



7 Sites operated over 20 years

* 1991 based on two sites only

Figure 9h: 13-Year Trend for O_3



23 Sites operated over 13 years

responsible for the large number of 1-hour exceedances there. (See Section 25.0 for a case study analysis of SO_2 in Sudbury).

Most of the SO_2 emissions are due to large point sources in Ontario. As shown in the SO_2 emission trend plot (Figure 11), smelters contribute about half of the sulphur dioxide emissions. The SO_2 emissions from smelters have dropped 75% since 1970. With the introduction of tighter emission controls, public information on daily air quality and low sulphur fuel, province-wide SO_2 emissions were reduced by 70% compared to 1970 and about 40% from 1980. The lower SO_2 emissions in 1978, 1979, 1982 and 1983 were related to production shutdowns/decreases at major smelters. The Acid Rain Countdown program initiated in 1987 has produced some of the SO_2 emission reductions seen in 1990 and 1991. In 1991 the SO_2 emissions from electricity utilities are generally below the Countdown Acid Rain cap of 175 kilo-tonnes. The emissions from smelters were also reduced with the commissioning of the first phase of their SO_2 abatement program.

22.2 10-Year Trend in Carbon Monoxide (CO)

The trend in mean annual CO concentrations at locations which possess a 10-year record is shown in Table 8b and is summarized for the province in Figure 12. From 1982 to 1983 mean ambient CO levels improved by about 27%; however, for the past nine years, average CO levels have remained constant at approximately 0.8 ppm with a minor peak 0.9 ppm in 1989. (See section 25.0 for a case study analysis of CO levels in downtown Toronto).

The transportation sector accounts for about 75% of carbon monoxide emissions (Figure 13). Estimates of carbon monoxide emissions from 1982 to 1991 show little change in total emissions until 1986 with a slow steady decrease since that time. Despite an increase in vehicle kilometers travelled over the last decade, (Figure 14); emissions from the transportation sector have decreased by about 30% through better emission controls.

22.3 10-Year Trend in Nitrogen Dioxide (NO_2) and Nitric Oxide (NO)

The 10-year trend in the annual average NO_2 concentration at selected Ontario cities is summarized in Table 8c and graphically presented in Figure 15. NO_2 levels have remained relatively constant over the 10-year period with the exception of 1989 to 1991 which shows a 10% drop. Nitric oxide levels over the same 10-year period show a little more year to year variation, and more than a 20% drop is evident between 1989 to 1991 (Figure 16).

The emission of NO_x showed little variation from years 1982 to 1989 (Figure 17). However, with the introduction of new vehicle emission standards in 1988, there was a downward trend of emissions from the transportation sector from 1989 onwards even with the increase in vehicle kilometers travelled (Figure 14). Since the transportation sector produces more than 60% of total nitrogen oxide emissions (Figure 17), the new vehicle emission standards have resulted in an overall decrease in emissions of more than 10% from 1989 to 1991.

Figure 10:
10-Year Trend for SO_2

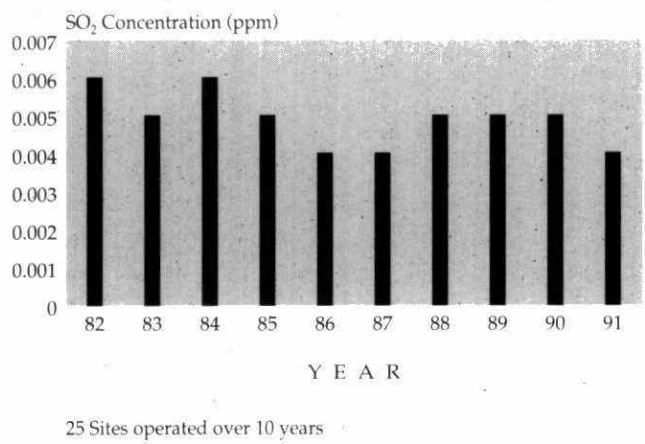


Figure 11:
Ontario Sulphur Dioxide Emission Trend (1970 to 1991)

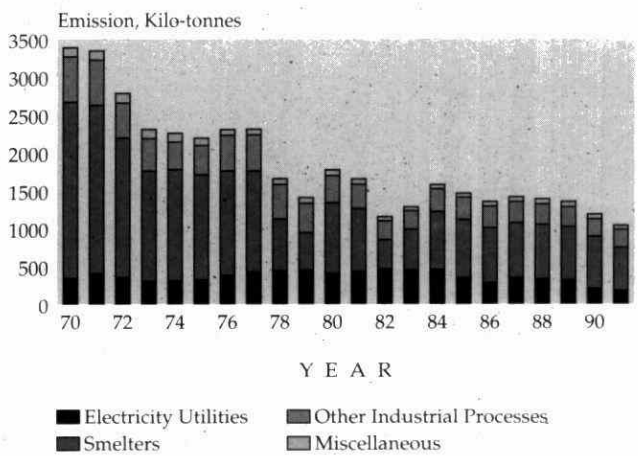
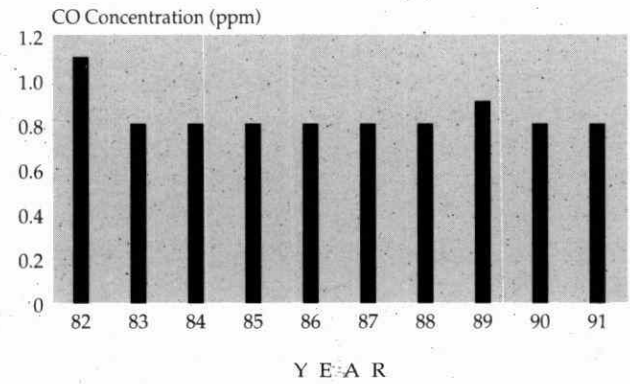


Figure 12:
10-Year Trend for CO



16 Sites operated over 10 years

Figure 13:
Ontario Carbon Monoxide Emission Trend
(1982 to 1991)

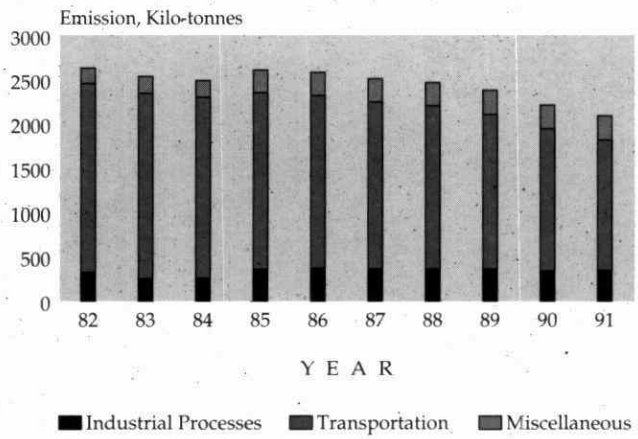


Figure 14:
Ontario Vehicle-Kilometers Travelled
(1982 to 1991)

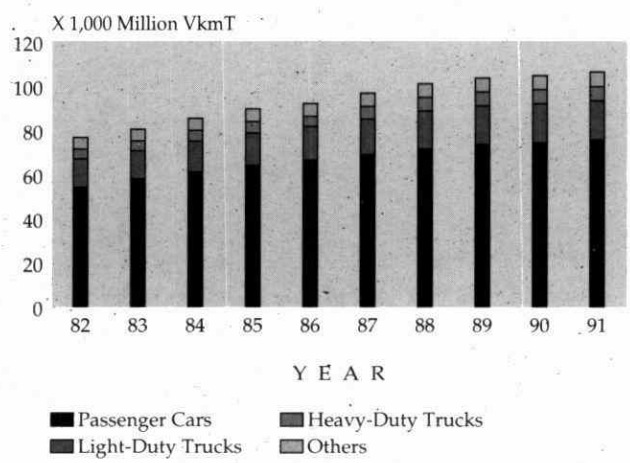
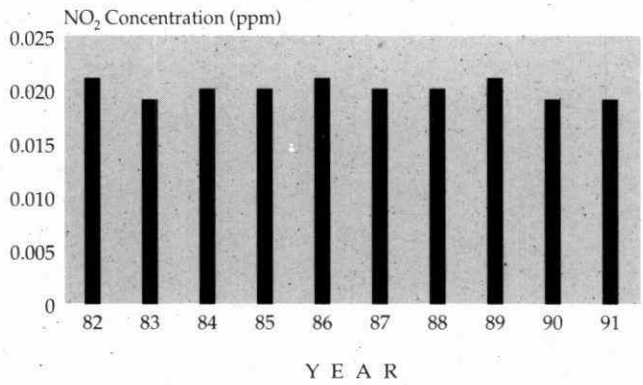
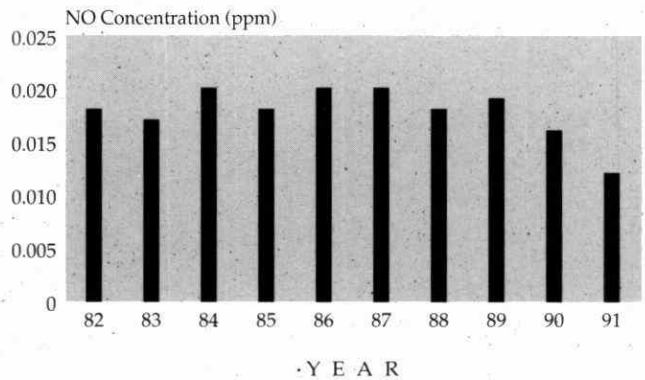


Figure 15:
10-Year Trend for NO_2



17 Sites operated over 10 years

Figure 16:
10-Year Trend for NO



17 Sites operated over 10 years

Figure 17:
Ontario Nitrogen Oxides Emission Trend
(1982 to 1991)

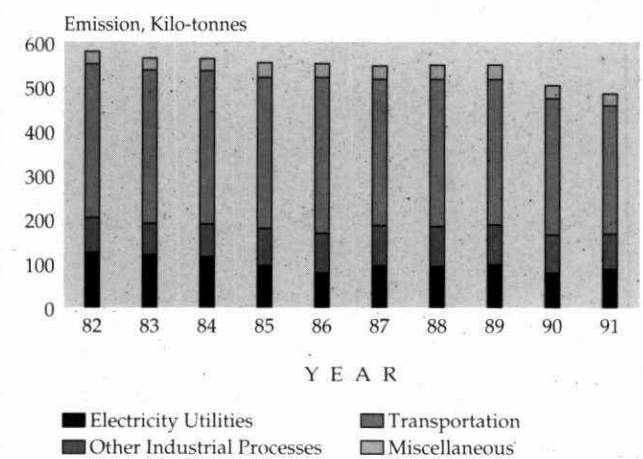
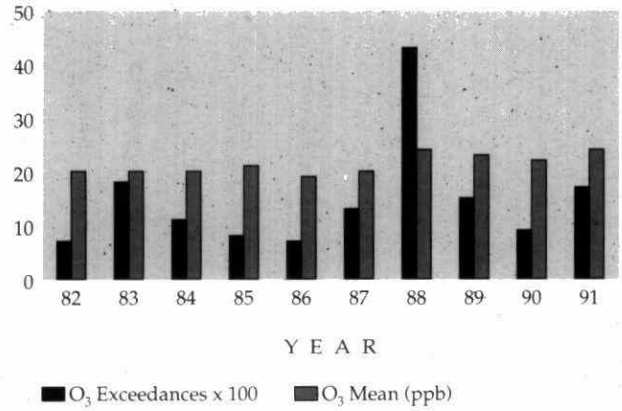


Figure 18:
10-Year Trend for Ozone



23 Sites operated over 10 years

Figure 19:
Ontario VOC Emission Trend
(1982 to 1991)

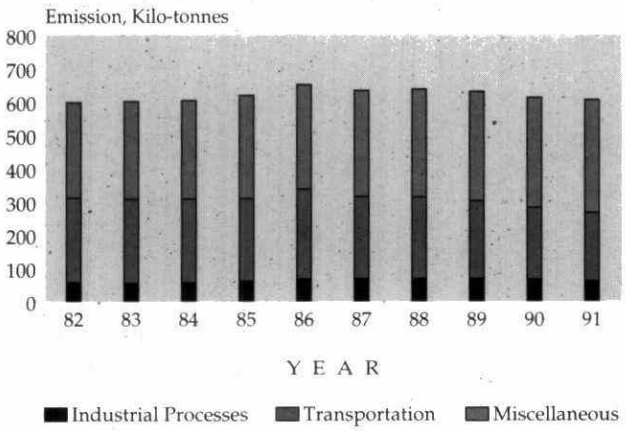
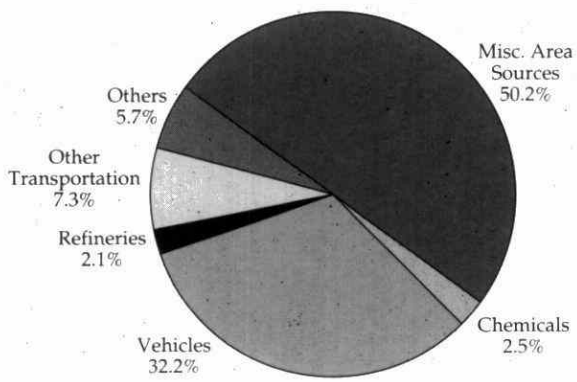


Figure 20:
Ontario VOC Emissions by Sectors
(Annual Emission 630 kT)



22.4 10-Year Trends in Ozone (O_3)

The 10-year trend in mean annual ozone levels and number of exceedances of the provincial 1-hour AQC (80 ppb) for 23 ozone sites (1982-1991) are displayed in Figure 18 and Table 8e. The relatively high ozone concentrations in 1983, 1988 and 1991 are likely attributed in part to hot, dry stagnant summertime conditions (high temperatures and strong solar insolation). The interpretation of the 10-year ozone trends is difficult due to the compounding factors of meteorology and emission changes. Just as the increase in 1983, 1988 and now 1991 is attributed in part to the meteorological conditions, the relatively lower ozone concentrations in 1989 and 1990 are likely due, in part, to meteorological conditions being less favourable for ozone formation. However, it should be noted that the provincial mean annual ozone level for the last 4 years (1988 to 1991) is higher than the mean during the period 1982 to 1987. (See Section 27.0 for a detailed ozone analysis).

There is little variation in the VOC emission trend for the last 10 years (Figures 19 & 20). As a result of new vehicle emission standards and the economic slowdown, emissions from the transportation and industrial processes showed a small decrease from 1989 to 1991.

It should be noted that fugitive, forest fire and natural VOC emissions were not considered in this emission trend. It is estimated that fugitive sources will increase the provincial total by 5%, while natural sources emissions may be as high as 3 times the anthropogenic sources.

The introduction of lower Reid Vapour Pressure (RVP) gasoline (from 11.5 psi to 10.5 psi) in summer months beginning in 1989 resulted in a 2.2% reduction in provincial VOC emissions (Figure 21). Similar or larger reductions in the RVP have been introduced for states south of Ontario since 1989. As a result, the reduction in reactive hydrocarbon emissions from the transportation sector including gasoline handling has been estimated to be about 5% (Figure 21). The net reduction in reactive hydrocarbon emissions is relatively small compared to the total man-made plus natural emissions. Its impact on ozone production is, therefore, difficult to see in the trend of O_3 for 1989 to 1991. The number of O_3 exceedances during the 1989 to 1991 period was comparable to or higher than the results during 1982 to 1987 when the RVP was 11.5 psi. Any trend in ozone during 1989 to 1991 can be attributed mostly to meteorological variability as was the case in 1988.

22.5 10-Year Trends in Suspended Particles (SP)

The trend in mean annual SP concentration at selected Ontario cities is shown in Table 8f and summarized for the province in Figure 22. Fine particulate, as determined by SP, has remained relatively constant over the 10-year period 1982-1991. However, as previously stated, the 24-hour AQC for suspended particles was the second most frequently exceeded AQC during 1991.

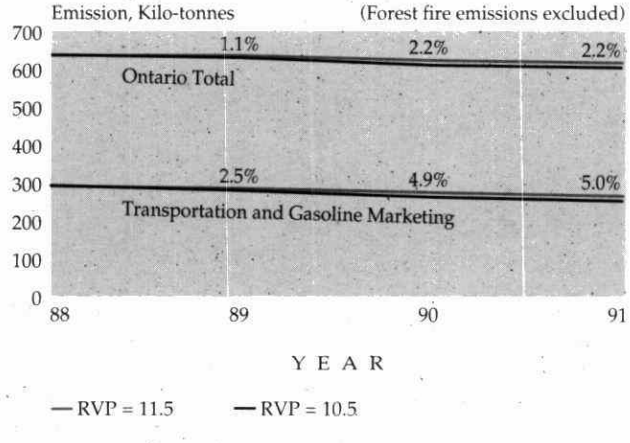
22.6 10-Year Trend in Total Reduced Sulphur (TRS)

Table 8g shows the ten-year trend in mean annual TRS for selected Ontario cities while Figure 23 shows the provincial trend with a minimum composite mean in 1985 and a general decreasing trend over the last five years. The minimum in 1985 is due to production shutdowns/decreases at the kraft pulp mill in Cornwall and to the use of monitors which under estimated TRS levels in Fort Frances. (See section 25.0 for a case study analysis of TRS odour problems in Fort Frances).

22.7 10-Year Trends in Particulate Matter (TSP)

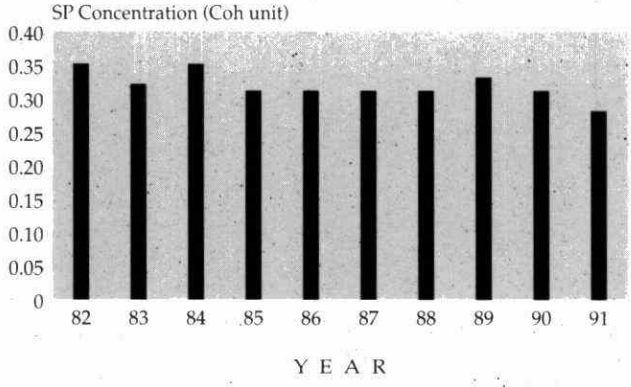
The trend in mean annual TSP concentrations at 31 sites which possess a 10-year record is shown in Table 8h and summarized for the province in Figure 24. Particulate levels across Ontario have improved by 10% over the 10-year period 1982 to 1991. However, as stated earlier, 60% of the stations measuring for TSP exceeded the 24-hour AQC at least once and 12% exceeded the annual criterion. Even though particulate levels province-wide are decreasing, levels at some sites in major urban centres such as Hamilton, Windsor and Toronto continue

Figure 21:
Reduction in Ontario VOC Emission Due to Lower Gasoline RVP in Summer



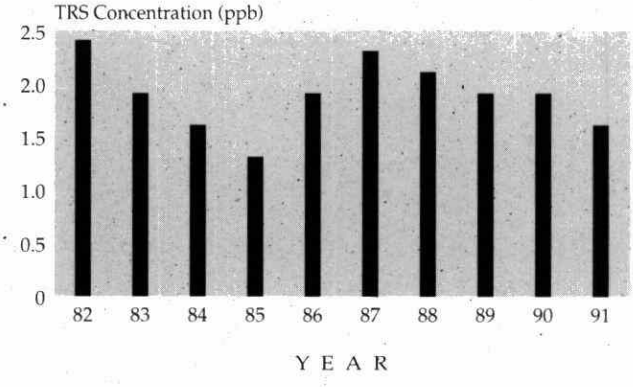
RVP: Reid Vapour Pressure (pound/sq.in.)
1989: Use of RVP 10.5 gasoline in 2 summer months
1990,91: Use of RVP 10.5 gasoline in 3 summer months

Figure 22:
10-Year Trend for SP



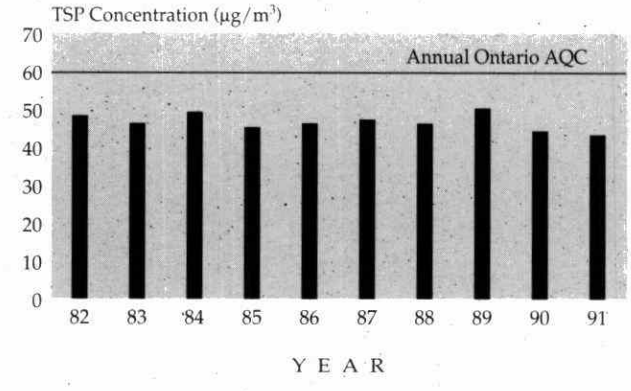
14 Sites operated over 10 years

Figure 23:
10-Year Trend for TRS



6 Sites operated over 10 years

Figure 24:
10-Year Trend for TSP



31 Sites operated over 10 years

Figure 25:
Ontario Particulate Emission Trend
(1982 to 1991)

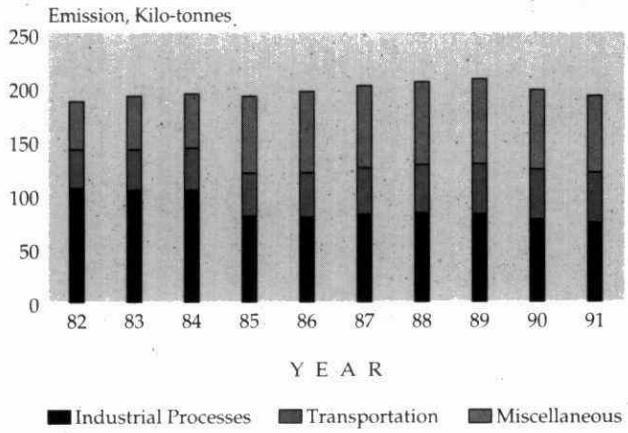
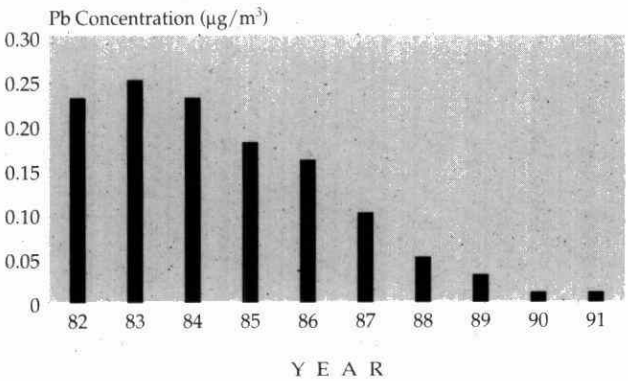
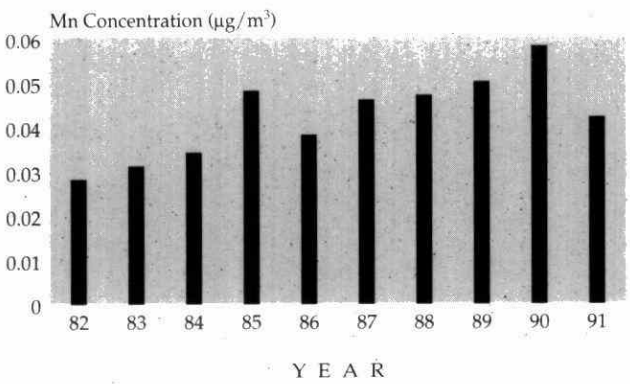


Figure 26:
10-Year Trend for Pb in TSP



16 Sites operated over 10 years

Figure 27:
10-Year Trend for Mn in TSP



10 Sites operated over 10 years

to exceed the Ontario AQC (See Section 25.0 for a case study analysis of particulate levels in Hamilton).

The particulate emissions showed a slight upward trend from 1982 to 1989 and a downward trend from 1989 (Figure 25). The emission reductions between 1989 and 1991 were from the industry and other sectors. Emissions from transportation remained stable from 1989 to 1991.

Particulate emissions from fugitive sources and forest fires were not included in the emission trend analysis. The emissions from forest fires vary from year to year and are thought to be as high as 5 times the anthropogenic sources. Contributions from fugitive sources such as road dust, construction and surface erosion have not yet been assessed. Since fugitive emissions from sources such as entrained road dust can be the dominant source of ambient TSP levels, the trend in measured TSP values would not necessarily follow the emission trend.

22.8 10-Year Trend in Lead (Pb)

Pb levels in air have improved significantly over the past 10-year period as shown in Figure 26. The ambient Pb levels represent general urban conditions predominantly reflecting automotive sources. The trend at selected Ontario cities is shown in Table 8i. Pb levels have declined by 99% during the period 1982 to 1991. This decline is due to the increased use of unleaded gasoline in catalyst-equipped cars and the reduced Pb content in leaded gasoline. Pb emissions from gasoline use have been effectively eliminated during 1991 because the addition of Pb to gasoline was prohibited after December 1, 1990.

As mentioned earlier, the highest Pb concentrations are measured in the vicinity of secondary Pb processing plants. These plants tend to be located in urban areas and therefore remain an environmental concern. Emissions from these plants are being closely monitored.

22.9 10-Year Trend in Manganese in TSP (Mn)

Table 8j provides the ten-year trend for average Mn concentrations at the stations where a 10-year record exists. Figure 27 summarizes the data for the province. Mn levels have increased by 50% over the last 10 years. In order to raise the fuel octane level in the absence of lead, a manganese compound was added to gasoline. This manganese compound is a contributing factor for the increase in Mn levels in Ontario. It should also be noted that emissions from the iron and steel industry con-

tribute to elevated Mn levels. These levels are well below the provincial AQC.

22.10 10-Year Trend in Copper in TSP (Cu)

The trend in mean ambient Cu levels is shown in Table 8k and summarized for Ontario in Figure 28. Cu levels have decreased by 55% over the last 10 years. It should be noted that in the earlier years the copper data may have been affected by the contamination from the copper windings of the Hi-vol motor. No attempt has been made to correct the data.

22.11 10-Year Trend in Iron in TSP (Fe)

The trend in mean annual Fe concentrations is shown in Table 8l and is summarized for the province in Figure 29. Fe levels have remained constant over the last 10 years.

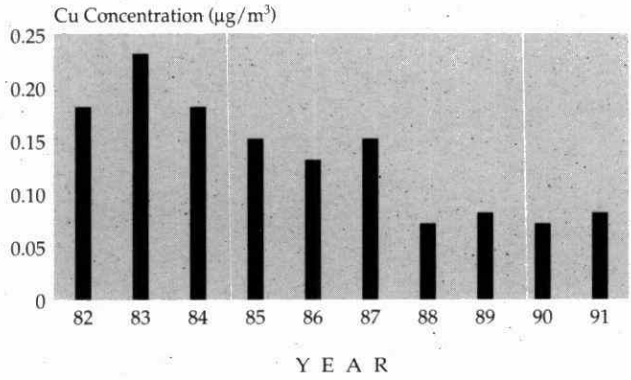
22.12 10-Year Trend in Nitrate in TSP (NO_3^-)

The trend in mean annual nitrate at locations which possess a 10-year record is shown in Table 8m and summarized for the province in Figure 30. The nitrate variability from year to year is largely related to meteorological variability since nitrate is primarily the result of medium and long range transport of air pollution.

22.13 10-Year Trend in Sulphate in TSP (SO_4^{2-})

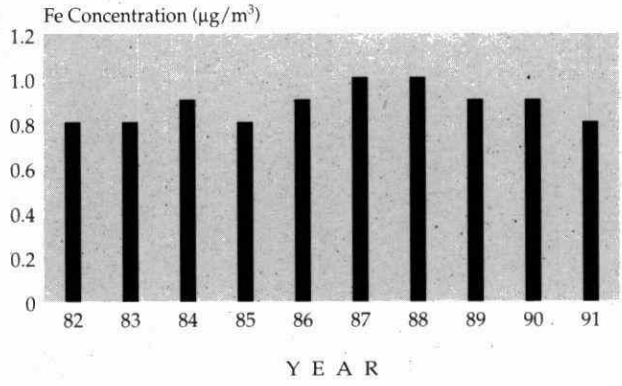
The trend in mean annual sulphate levels is shown in Table 8n and summarized for the province in Figure 31. As in the case of nitrate, the sulphate variability may also be explained by meteorological variability.

Figure 28:
10-Year Trend for Cu in TSP



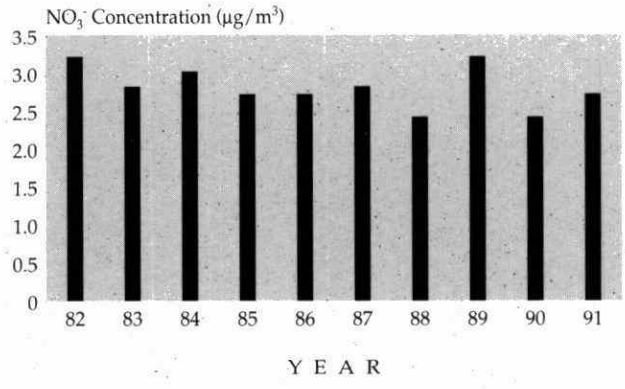
9 Sites operated over 10 years

Figure 29:
10-Year Trend for Fe in TSP



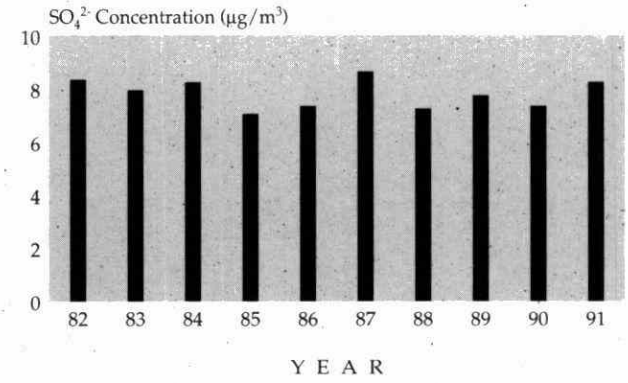
11 Sites operated over 10 years

Figure 30:
10-Year Trend for NO_3^- in TSP



16 Sites operated over 10 years

Figure 31:
10-Year Trend for SO_4^{2-} in TSP



16 Sites operated over 10 years

23.0 Ambient Air Quality Comparison of Selected Cities Around the World

In the "Air Quality in Ontario, 1990" report, a section was included comparing ambient air quality levels for SO_2, NO_2, CO, O_3 and TSP in six selected North American cities using data for 1989.

In this section a brief comparison of the 1989 ambient air quality levels for the same five pollutants for major cities around the world is given (Figure 32).

Most literature reporting and comparing ambient air quality for cities around the world is published by the United Nations Environment Programme (UNEP) and the World Health Organization (WHO). Their objective through the Global Environment Monitoring System (GEMS/Air) network is to compile and analyze air quality data on a global basis. The GEMS/Air monitoring project began in 1973 and has gradually increased in size to over 50 participating countries and approximately 200 monitoring sites around the world.

In most cities, there are three GEMS/Air monitoring stations: one located in a residential area, one in a commercial area and one in an industrial area. It is believed that the data obtained from these stations permit a reasonable evaluation of minimum and maximum levels, and of long-term trends of average concentrations.

The Ministry has obtained ambient air quality data from all available sites operating within the metropolitan area of each city during 1989, reasoning that the use of all available data may better represent the air quality of the city by providing a broader coverage.

There are some problems, however, with reporting all available data because in most of these cities, the actual location of the monitoring site and its proximity to sources affecting the measured air quality levels is not always known. For example, the Mission site in down-

Figure 33a:
Annual SO_2 Averages at Monitoring Sites in Selected Cities 1989

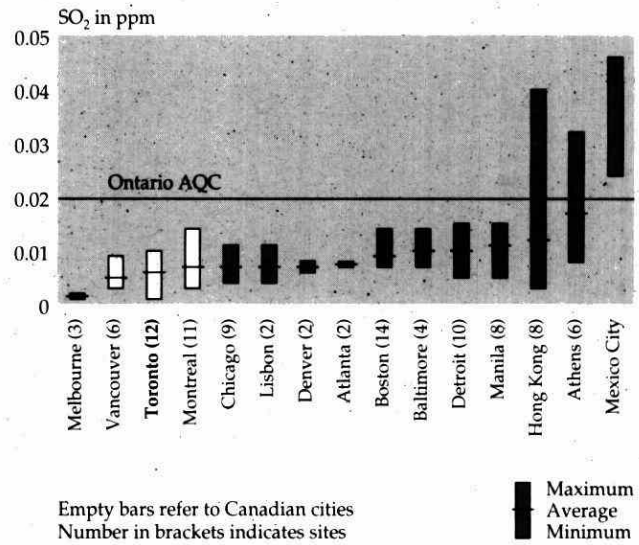


Figure 32:
Location of Cities Used in International Air Quality Comparison

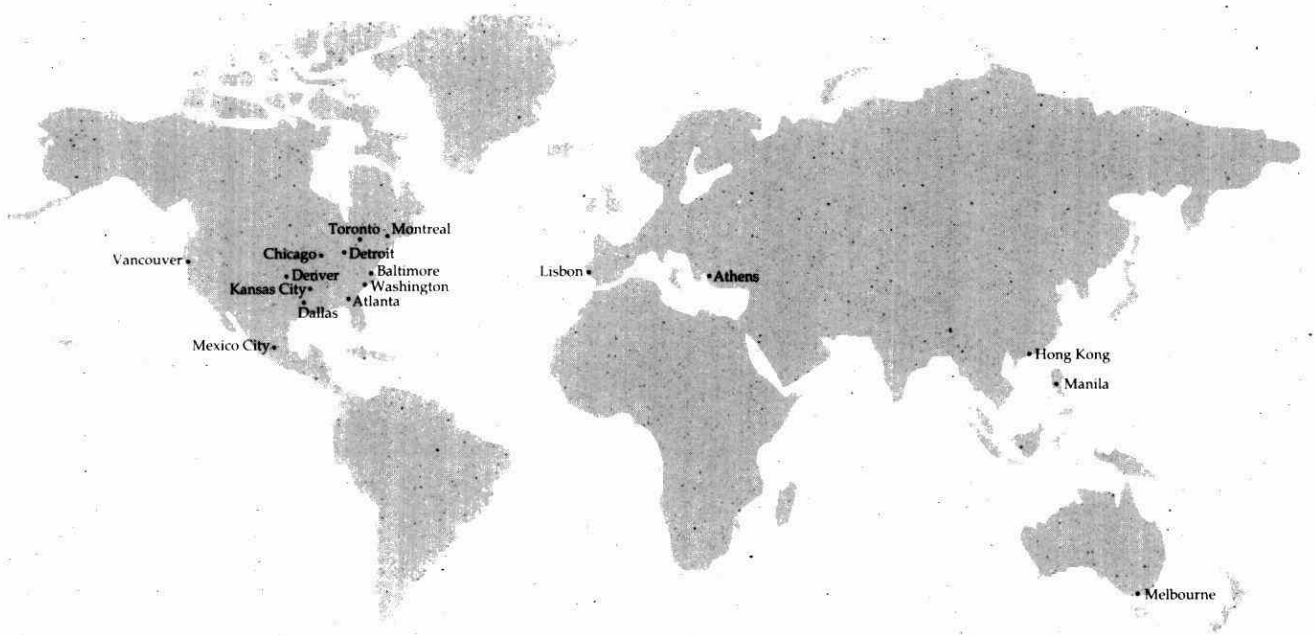


Figure 33b:
Annual TSP Averages at Monitoring Sites in Selected Cities 1989

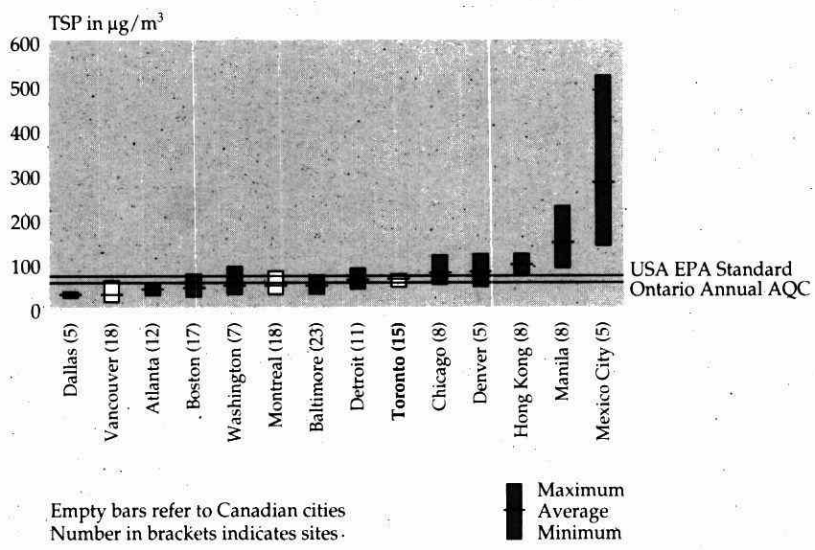
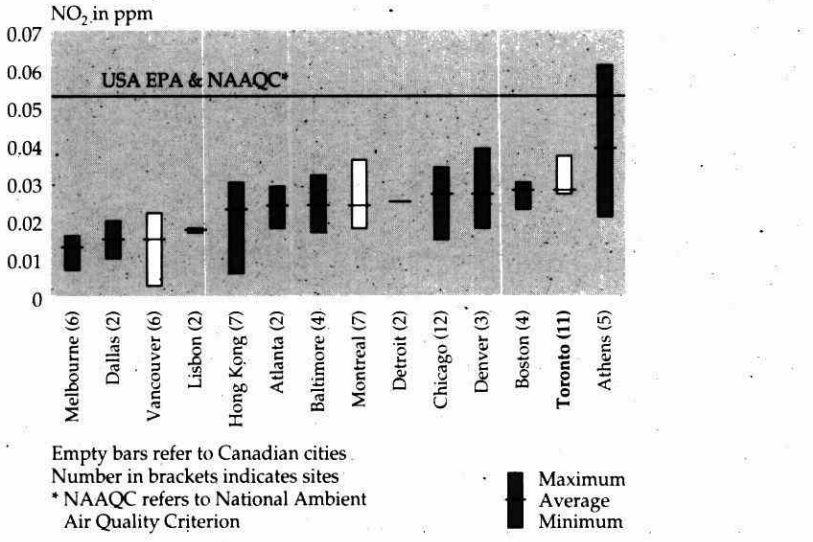


Figure 33c:
Annual NO_2 Averages at Monitoring Sites in Selected Cities 1989



town Toronto was sited in an area of high density slow moving traffic along the Yonge Street corridor in order to monitor the street canyon effect on vehicle pollutant levels. As expected, the Mission monitor records the highest levels of vehicle related pollutants annually.

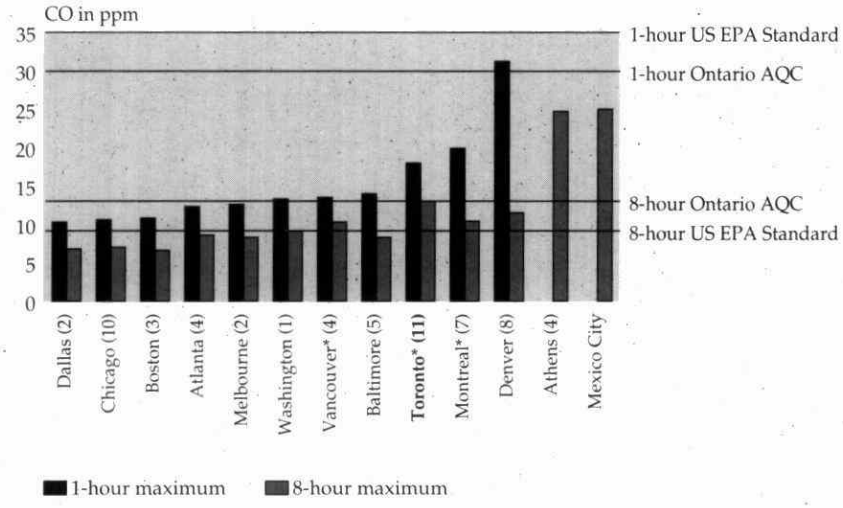
In this comparison we cannot use the overall ranking system which was applied to the previous comparison of the six selected North American cities published in "Air Quality in Ontario, 1990" because not all cities monitor for the five pollutants and not all cities report a full range of statistical information for a direct comparison.

A summary of the annual SO_2 average concentration levels for the cities presented in Figure 33a shows that SO_2 still constitutes a major part of the urban air pollution problem in some major cities around the world. This is not the case for Toronto, however, because during the early to mid 1970s there was a major shift to the use of cleaner burning fuels for residential and commercial space heating, and also in various industrial activities. As a result, ambient air quality levels of SO_2 in Toronto during this period showed significant improvements and concentrations have gradually decreased to levels well within the provincial AQC.

Total suspended particulate matter (TSP) is a good indicator of urban air pollution problems. As depicted in Figure 33b, the 1989 annual TSP averages in selected cities indicate that Toronto is one of the heaviest polluted cities in North America with the composite mean exceeding the provincial AQC for TSP. However, in comparison to cities such as Hong Kong, Manila and Mexico City which are also displayed in Figure 33b, ambient air quality levels of TSP in Toronto are much lower.

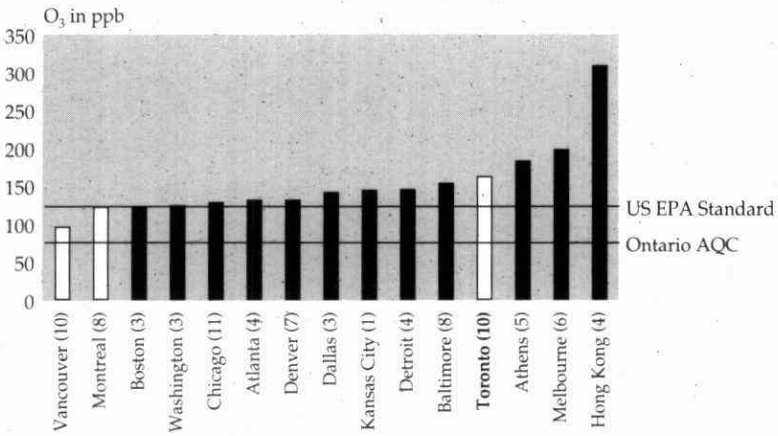
Annual average levels of NO_2 are relatively low in each of the cities presented in Figure 33c, and with the exception of Athens are well below the standard established by the US EPA and the Canadian National Ambient Air Quality Objectives (NAAQC). In the previous comparison performed for the six North American cities the highest 1989 annual mean level (composite average) was recorded at sites in Metro Toronto and Boston and was largely attributed to motor vehicle emissions. With the addition of eight other major cities around the world in this comparison, only the city of Athens records annual levels of NO_2 greater than that of Toronto and Boston.

Figure 33d:
Comparison of CO levels at Monitoring Sites in Selected Cities 1989



Number in brackets indicates sites
* Refers to Canadian cities

Figure 33e:
Maximum 1-Hour Average O_3 Levels at Monitoring Sites in Selected Cities 1989



Empty bars refer to Canadian cities
Number in brackets indicates sites

It should be noted that the elevated NO_2 levels reported for Toronto were recorded at the "Mission" monitoring site which was established to monitor the street canyon effect on vehicle related pollutants in downtown Toronto.

A comparison of the 1989 CO levels in selected cities is presented in Figure 33d. The information presented is reported in terms of the 1-hour and 8-hour maximum value recorded during the year. This provides information on the air quality during the "worst case" for that year as well as an indication of the potential for air pollution incidents.

The results in Figure 33d show that the 1-hour and 8-hour maximum levels for CO measured in Toronto are somewhat higher than most North American cities. Most cities outside of North America do not monitor for CO, hence a comparison of CO levels on a global basis is limited. The highest 8-hour maximum, which is widely used for comparison because it is the more restrictive limit, is recorded in Mexico City, followed by Athens and then Toronto. It should be noted that maximum levels in Toronto were recorded at the "Mission" site which was described earlier in the NO_2 comparison. The Mission 1-hour and 8-hour CO maxima were respectively 30% and 60% higher than any other station in Toronto. The significantly higher CO levels measured in Mexico City and Athens are largely attributed to severe traffic problems, poor emission controls on vehicles and limited pollutant dispersal due to existing geographical setting and meteorological conditions.

Ozone is a pollutant which is not a direct reflection of emissions from a city, rather, it is a secondary pollutant with a large component attributed to long range transport in eastern North America. The maximum 1-hour O_3 levels in selected cities for 1989 is shown in Figure 33e. Of the 15 cities listed, Toronto recorded the 4th highest 1-hour maximum during 1989. Hong Kong, Melbourne and Athens all recorded 1-hour maximum levels higher than Toronto .

24.0 Ambient Air Quality Comparison - S. Ontario vs N. Ontario

In the following section, the air quality levels at various industrial and urban centres of Ontario are discussed. Special attention is given to southern versus northern Ontario in view of the difference in distribution of industries in these two regions. Furthermore, southern

Ontario is more often affected by long range transport of pollutant species from the U.S.

Ambient air quality concentrations for selected criterion pollutants (SO_2, CO, NO_2, O_3 and TSP) were compared for southern Ontario versus northern Ontario for 1991. Data from representative monitoring sites (excluding sites which are biased by local sources) in Sudbury, North Bay, Sault Ste Marie and Thunder Bay were used to represent northern Ontario while data from representative monitoring sites (excluding sites which are biased by local sources) in Windsor, London, Hamilton and Toronto were used to represent southern Ontario.

The range of annual means and the range of 1-hour, 8-hour and 24-hour maximum concentrations are presented in Table 9 for northern versus southern Ontario for 1991. Also included in the table is the composite number of 1-hour AQC exceedances for SO_2, CO, NO_2 and O_3 and the percentage of exceedances for the 24-hour TSP AQC.

For SO_2, there is a larger range in annual mean concentration in northern Ontario and also, there were 7 exceedances of the 1-hour SO_2 AQC recorded in northern Ontario and none recorded in southern Ontario during 1991. SO_2 criterion exceedances in northern Ontario are primarily reflecting the presence of the INCO and Falconbridge smelter operations for the Sudbury site.

For CO, the levels in southern Ontario are significantly higher. The annual means are approximately 3 times greater than the annual means in northern Ontario. The range of 1-hour and 8-hour maximum values are also higher than those of northern Ontario (Table 9). Elevated carbon monoxide levels are strongly related to auto-

Table 9: Comparison of Air Quality Levels in Northern Ontario Versus Southern Ontario (1991)

	SO_2 (ppm)		CO (ppm)		NO_2 (ppm)		O_3 (ppb)		TSP ($\mu g/m^3$)	
	S. Ont.	N. Ont.	S. Ont.	N. Ont.	S. Ont.	N. Ont.	S. Ont.	N. Ont.	S. Ont.	N. Ont.
Range of Annual Mean	0.005 - 0.007 (0.006)	0.000 - 0.005 (0.002)	0.7 -1.1 (1.0)	0.2 - 0.4 (0.3)	0.019 - 0.029 (0.024)	0.010 - 0.012 (0.011)	18 - 23 (20)	16 - 27 (24)	51 - 61 (54)	30 - 38 (34)
Range of 1 Hr. Max	0.06-0.11 (0.09)	0.04 - 0.75 (0.26)	8 -10 (9)	6 - 10 (7)	0.10 - 0.12 (0.11)	0.06 - 0.16 (0.09)	102 - 107 (103)	70 - 103 (89)	N/A	N/A
Range of 8 Hr. Max	N/A	N/A	4 - 6 (5)	2 - 4 (3)	N/A	N/A	N/A	N/A	N/A	N/A
Range of 24 Hr. Max	0.02 - 0.04 (0.03)	0.01 - 0.05 (0.03)	N/A	N/A	0.05 - 0.07 (0.06)	0.03 - 0.07 (0.06)	54 - 72 (64)	44 - 79 (60)	137 - 600 (261)	105 - 140 (119)
# Exceedences	0	7	0	0	0	0	171	55	2 - 7% (5%)	0 - 3% (1.0%)

Figures in brackets are the composite mean.
Geometric means are used for TSP.
N/A refers to not applicable.

mobile use and emissions from combustion sources in high density urban areas.

For NO_2, the composite mean for southern Ontario is 0.024 ppm compared with 0.011 ppm for northern Ontario. The 24-hour maximum concentrations in southern Ontario are also significantly higher than those of northern Ontario (Table 9). Similar to CO, the presence of high temperature combustion sources including the automobile, power plants and incinerators in high density urban areas account for elevated levels of this contaminant.

For O_3, the range of annual means in northern Ontario is higher than that reported for southern Ontario; however, the opposite is true for the 1-hour and 24-hour maximum concentrations. The composite number of exceedances of the provincial 1-hour AQC is 171 in southern Ontario compared to 55 in northern Ontario. Long range transport is a significant contributor to elevated ozone levels across Ontario.

TSP levels in southern Ontario urban centres are significantly higher than the levels recorded in northern Ontario urban centres. In 1991, the southern Ontario composite geometric mean of TSP was 54 $\mu g/m^3$ compared to a northern Ontario composite geometric mean of 34 $\mu g/m^3$. Also the percentage of exceedances of the 24-hour AQC for TSP and the range in 24-hour maximum values in southern Ontario were higher than those found in northern Ontario.

25.0 AIR QUALITY IN SELECTED PROBLEM AREAS WITHIN ONTARIO

25.1 Case Study 1 - The Particulate Problem in Hamilton

One major air pollution problem in Hamilton has been and continues to be TSP. The average annual geometric mean TSP levels are shown to have decreased significantly over the years (Figure 34). At present, however, sites situated near the industrial sector along Hamilton Harbour and in the downtown core measure TSP levels in non-compliance with both the daily and annual AQC. Since these areas are also densely populated, there is concern because this percentage of Hamilton's population is being exposed to undesireable TSP levels.

In this section, an in-depth analysis will be provided as to the time-related distribution of TSP episodes and the prevailing meteorological and climatological conditions during these events. Also, an attempt will be made to differentiate the non-attainment areas from those areas in the city which experience acceptable particulate air quality. The population exposed to undesireable levels

Figure 34:
Range of Annual Mean TSP Levels at Monitoring Sites in Hamilton, 1971-1991

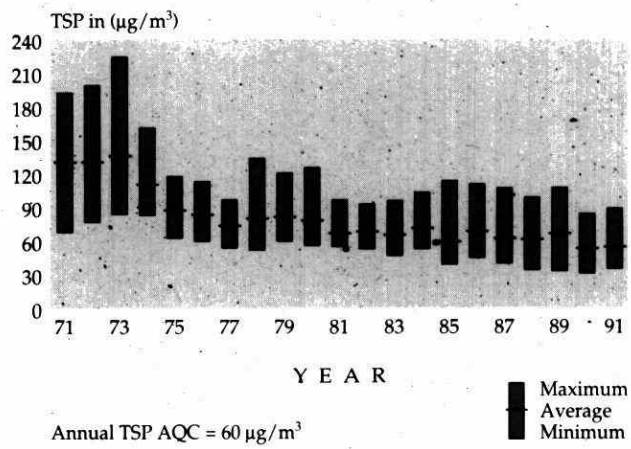
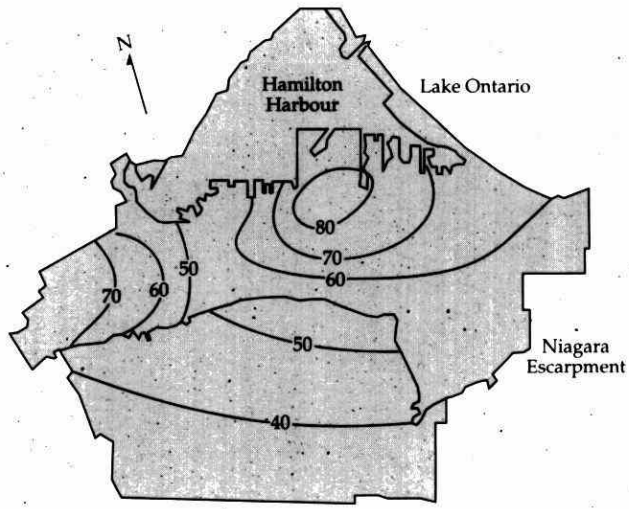


Figure 35:
Isopleth Map - Annual Average TSP Levels in Hamilton 1991

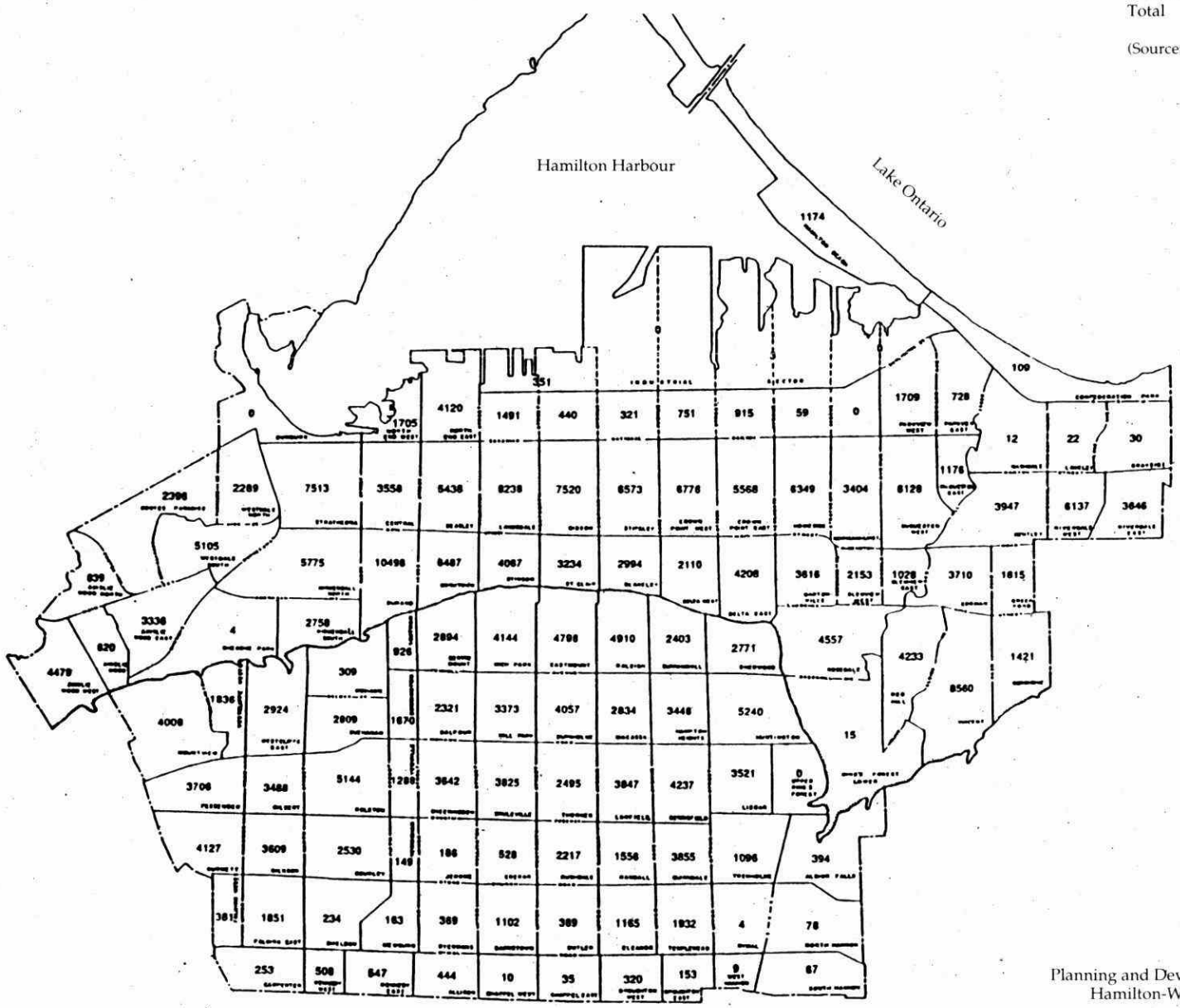


would, ideally, provide the best measure as to the extent of the particulate problem; however, due to the limitation on the number of monitors available, the existing network does not provide a full coverage of the city to perform this type of detailed assessment. None-the-less, an effort can be made to approximate the population exposed to undesirable levels by using the available data to generate an isopleth map and also by using this data as an indicator of particulate levels in other areas of the city with similar characteristics, where monitoring is not performed. Isopleth mapping is a graphical technique which can be used to interpolate areas of equal concentrations from the monitoring data. The isopleth map (Figure 35) was generated using the average annual geometric mean TSP levels at sampling locations in

Figure 36: Hamilton Neighourhood Populations, 1988

Hamilton Mountain	123,129
Lower City	188,218
Total	311,347

(Source: 1988 Assessment)



Planning and Development Department
Hamilton-Wentworth Region

Hamilton for 1991. It should be noted isopleths were drawn separately for the lower city and the area above the escarpment. The isopleths were drawn to scale and overlaid on a map showing the neighbourhood populations in the city of Hamilton for 1988 (Figure 36). An estimation of the population exposed to undesirable levels was determined by summing up the populations in those areas where annual mean TSP levels are observed to exceed the annual AQC of 60 $\mu g/m^3$. The results show that approximately one-third of Hamilton's population are subjected to annual TSP concentrations considered to be undesireable. Again, it should be stated that due to the relatively small number of sampling sites used to generate this isopleth map, there is an uncertainty in these results. In addition, some of the monitoring stations have very localized effects, ie., traffic influence, and therefore TSP levels may improve dramatically at short distances from the Hi-vol sampler, which would not be represented here.

As mentioned previously, the industrial complex located along Hamilton Harbour is a source of man-made heat and pollution which affects various aspects of the local environment. The behavior and dispersal of particulate matter is largely dependent on a combination of various meteorological processes and topographic influences.

The urban heat island effect coupled with solar heating of the city during the day can produce a prolonged period with a lake breeze circulation cell when winds are light. The circulation would be significantly affected by the Niagara Escarpment which can result in pollutants emitted in the Hamilton Harbour industrial centre being trapped primarily in the central and west end of the city. The city of Hamilton is a prime example of the combination of all three factors in which the Niagara escarpment combines with the lake breeze and the urban heat island to result quite frequently in extended periods of high pollutant levels particularly in the spring and fall. Local emissions can be advected over the lower city by the lake breeze. The presence of the escarpment along with the warmer temperatures due to the urban heat island restrict the circulation in the lower city, resulting in high pollutant levels.

A seasonal distribution of ambient TSP levels is also observed for Hi-vol sampling locations in Hamilton. The percentage monthly distribution of daily TSP values exceeding the 24-hour AQC at Barton/Sanford St. in Hamilton for the past 20 years is displayed in Figure 37. This station was chosen as an example because of its extensive sampling record and also because TSP exceedances from year to year at this site generally parallel the results observed for the average of all TSP sites in Hamilton, as shown in Figure 38. The results are generally the same for the vast majority of monitoring sites in Hamilton and indicate that daily TSP levels exceed the criterion more often in the spring months, with May showing the greatest frequency from 1971 to 1991. This is explained by changes in meteorological conditions. As the warm southerly air masses move northward and pass over the relatively cold water of the lower Great Lakes the air mass is modified, creating a condition which can strengthen the temperature inversion, thus creating poor dispersion conditions. The differential heating between the land and water is normally more prevalent during the spring months.

Figure 37:
Percentage Monthly Distribution of TSP Exceedances at Barton/Sanford Sts. in Hamilton from 1971-1991

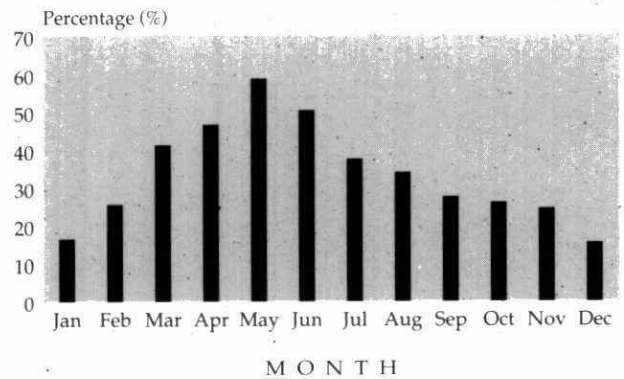
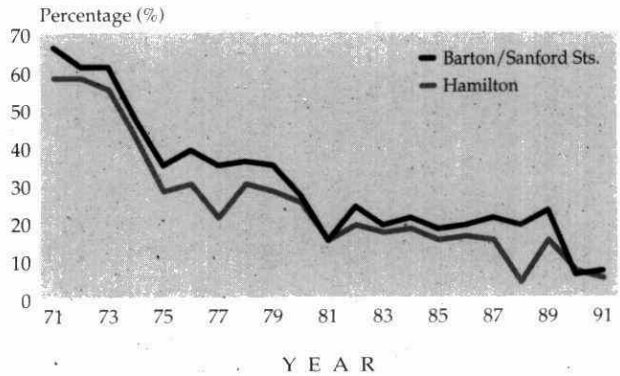


Figure 38:
Frequency (%) of TSP Levels Above the 24-hour AQC at Barton/Sanford Sts. and at Sites in Hamilton



TSP 24-Hour Criterion: 120 $\mu g/m^3$

25.2 Case Study 2 - Sulphur Dioxide in Sudbury

In the city of Sudbury, sulphur dioxide (SO_2) has been the contaminant of greatest concern since the Ministry began its routine monitoring in the early 1970s. The SO_2 monitoring network extended well beyond Sudbury's city limits and regional municipality to distances as far as 100 km to measure the impact of SO_2 emissions from the Inco and Falconbridge smelting operations. Changes have taken place to the SO_2 monitoring network throughout this time period. The majority of these changes consisted of relocating the monitoring stations closer to the city and in the vicinity of the smelters because of significant improvements in air quality outside of the Sudbury Region due to decreasing smelter emissions and greater dispersion due to Inco's tall stack at Copper Cliff.

The data used in this study were obtained from the SO_2 monitoring stations located directly within the city, thus representing concentrations to which the majority of the population is exposed. Monitoring stations in towns within the Sudbury basin area but outside of the city boundaries have on occasion recorded higher annual SO_2 levels.

The graph displayed in Figure 39 shows the measurable improvements in the quality of Sudbury's air for SO_2 over the years.

In a recent report (MOE 1990) a correlation was attempted between Inco's SO_2 emissions in tonnes/year and the annual mean SO_2 levels for Ash Street from 1969 to 1989. The results of this regression analysis statistically showed little correlation between these two parameters. This suggests that annual mean SO_2 levels in the Sudbury area are more strongly influenced by the frequency and intensity of short-term fumigations which in turn are dependent on the year to year meteorological variability.

The purpose of Inco's "tall" stack erected in 1972 was to release pollutants at a greater height, thus carrying the pollutants further from the source and dispersing them over a wider area, resulting in lower annual means and fewer exceedances of the provincial AQC. Although the tall stack did not completely eliminate the problem of short-term fumigations, noticeable improvements have been observed.

The SO_2 emissions reduction program imposed on both Inco and Falconbridge through the Ministry control orders is also responsible for the improvements realized in the freqency and severity of short term fumigations. Under this program, smelter emissions are curtailed through production cuts prior to the onset of adverse dispersion conditions. Due to current smelter technology limitations, the SO_2 ground level concentration control order limit is 0.50 ppm for a 1-hour running average computed from consecutive 5 minute averages.

The years 1988 to 1991 have shown a slight increase in the annual mean SO_2 levels on average (Figure 39) and a significant increase in the number of hours and days exceeding the provincial AQC. These increases are the direct result of the "Copper Cliff" SO_2 monitoring station commissioned in 1988 to measure the impact of roof-level fugitive emissions of SO_2 from the converter aisle at the Inco Ltd. Copper Cliff smelter. The Copper Cliff station is believed to be affected mostly by fugitive emissions with little (if any)

Figure 39:
Range of Annual SO_2 Levels at Monitoring Sites in Sudbury, 1971-1991

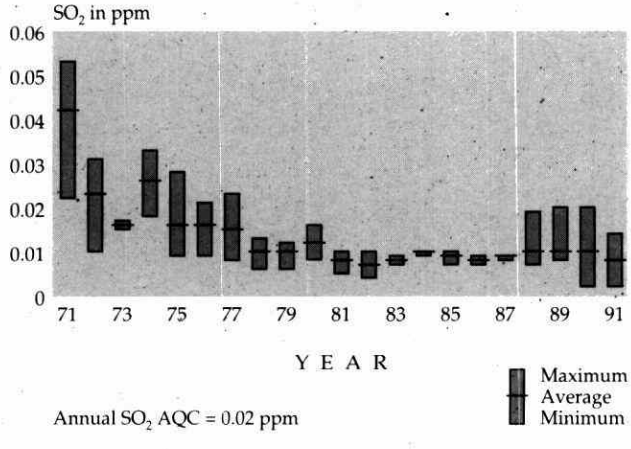
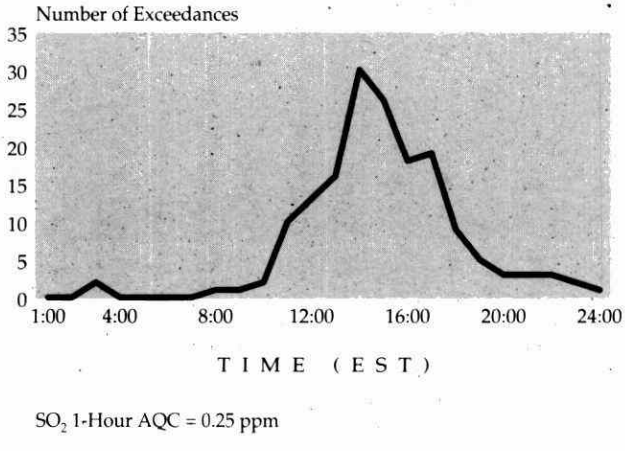


Figure 40:
Hourly Distribution of SO_2 Values Exceeding the 1-Hour AQC at Science North in Sudbury from 1984-1991



contribution from the "tall" stack. Conversely, the monitor at the Science North complex is believed to be mostly affected by elevated SO_2 releases (stack emissions) with little (if any) contribution from fugitive emissions.

Of the 158 hours which exceeded the 1-hour AQC at the Science North station from 1984 to 1991, the majority occurred between 1200 EST and 1700 EST (Figure 40). The meteorological data obtained from the CKNC tower indicate moderate winds and/or relatively unstable conditions (as indicated by the temperature lapse rate) prevailed for approximately 70% of these events. In some cases, pollutant concentrations were elevated and short-lived indicating that they were generally associated with plume looping events. The monthly distribution of these 158 exceedance hours appears in Figure 41. A definite pattern exists as the frequency of exceedances generally increases into the spring and summer months and decreases again with the on-set of fall and winter. No exceedances were recorded in July as smelter operations shut down for maintenance and vacation purposes.

While long-term trends have shown improvements in Sudbury's ambient SO_2 air quality, the potential for short term fumigations resulting in discomfort to people and possible injury to vegetation still exists. The Ontario Ministry of the Environment acknowledges this problem and is working towards ensuring that Inco and Falconbridge continue to operate within the requirements of their control orders and also work towards developing and implementing new control strategies and programs.

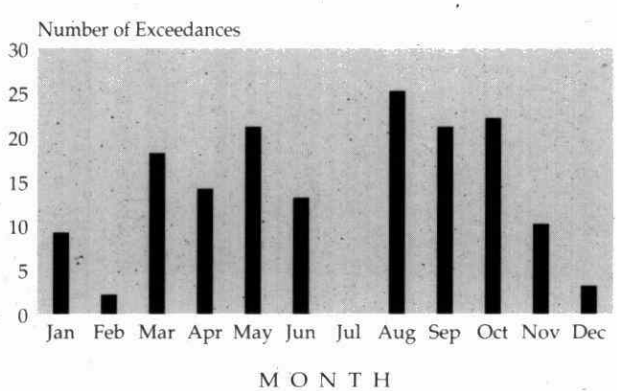
25.3 Case Study 3 - Carbon Monoxide Levels at "Mission" in Toronto

The data indicate that annual CO levels and violations of the provincial AQC in the city of Toronto have shown significant improvements over the past 20 years. However, short-term levels of CO occasionally present some concern in certain areas of the city. Our attention in this case study is centered on the "Mission" monitoring station, located at 381 Yonge St., because it usually records the highest CO levels in Metropolitan Toronto as well as in Ontario. This site is also responsible for the majority of the 1-hour and 8-hour exceedances of the provincial CO AQC.

By examining the "time" distribution patterns of elevated CO levels and relating this to several factors, including the volume of traffic, urban topographic effects and local meteorological conditions, an attempt will be made to explain the reason for higher CO levels at the "Mission" site in comparison to other sites in Toronto.

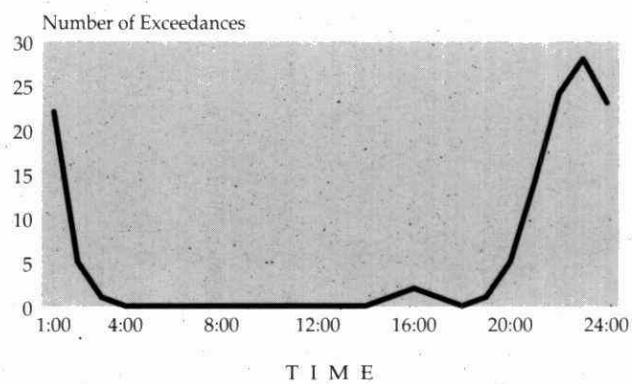
The number of vehicles (volume of traffic) is considered as being one of the factors since automobile emissions are the major source of CO in large urban areas. The volume of traffic along this section of Yonge Street is considered to be heavy, especially during the morning and evening rush hours, and on weekend nights. Typical diurnal patterns of CO levels show an increase during these rush traffic hour increments. In this section, however, we are more concerned with levels of carbon monoxide which exceed the 1-hour and 8-hour provincial AQC of 30 ppm and 13 ppm respectively. In addition, definite patterns are also observed directly related to the

Figure 41:
Monthly Distribution of SO_2 Values Exceeding the 1-Hour AQC at Science North in Sudbury from 1984-1991



SO_2 1-Hour AQC = 0.25 ppm

Figure 42:
Hourly Distribution of CO Values Exceeding the 1-Hour AQC at the Mission Site in Toronto from 1978-1991



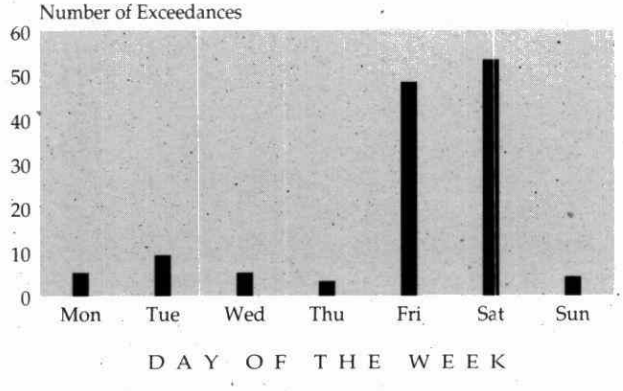
CO 1-Hour AQC = 30 ppm

time of day, day of the week, and seasonal and/or monthly distributions of these related episodes. There have been 127 hours which exceeded the 1-hour provincial AQC at the "Mission" station from November 1977 to December 1991 with the majority occurring in the late 1970s and early 1980s. The frequency of these violations are grouped and plotted on a 24-hour time scale as shown in Figure 42. The majority of these violations (87%) occurred during the late-evening between 2000 EST and 0100 EST. The frequency of these episodes are also plotted versus the day of the week, as shown in Figure 43. Approximately 80% of these violations occur on Friday and Saturday evenings and are attributed to the heavy and steady flow of slow moving traffic along Yonge Street. The monthly distribution of these episodes displayed in Figure 44 also reveals a prevailing seasonal distribution of these events with the majority (69%) occurring during the summer months of June, July, and August.

Now that the time we expect to observe high CO levels has been established, the prevailing meteorological conditions during these events will be examined. Since there is no available meteorological data at this site, wind speed and wind direction data at the 10 metre level from the Lawrence/Kennedy station in Scarborough were used. The corresponding wind data with elevated CO concentrations revealed that 80% of these episodes were associated with calm (<5 km/hr) conditions. Light to moderate winds (5 to 10 km/hr) were responsible for the remaining 20%. In all of these cases the meteorological data indicate that the atmosphere was characterized as being relatively stable to very stable throughout the day. In a normal diurnal cycle, the change of temperature with height varies systematically through 24-hours; temperature generally decreases with height in the daytime and increases with height during the night. Typically, this cycle leads to a limited morning peak in levels of carbon monoxide because the morning accumulation of rush hour emissions is countered by increased dilution as convection destroys the nocturnal temperature inversion. In contrast, during the evening, a surface temperature inversion begins to build, hence trapping and accumulating of CO as well as other vehicle related pollutants such as total nitrogen oxides (NO_x) and suspended particles (COH). Historical meteorological data from the CN tower site show that the strongest temperature inversions generally occur during the night. Light surface winds and a stable stratified boundary layer are not, however, restricted to only the evening hours. On some occasions such conditions were observed during the early morning rush hour; however, they are not as predominant because solar radiation, even diffused solar radiation during overcast conditions, creates a positive radiative flux resulting in some convective activity, hence dispersive activity.

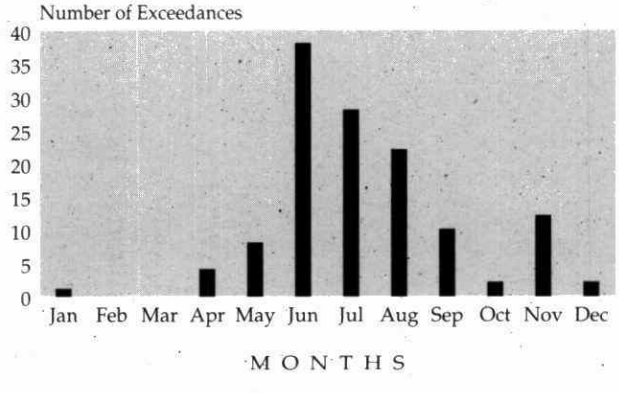
The urban topographic effects also play a significant role in the behaviour of the monitored CO patterns. Building shadowing and air-flow blocking are just two ways in which large buildings and structures create a unique microclimate and mesoclimate. Studies performed in Denver, Colorado (Neff, 1990) have shown that early surface temperature inversion formation due to building shadowing in combination with

Figure 43:
Daily Distribution of CO Values Exceeding the 1-Hour AQC at the Mission Site in Toronto from 1978-1991



Total Exceedances = 127
CO 1-Hour AQC = 30 ppm

Figure 44:
Monthly Distribution of CO Values Exceeding the 1-Hour AQC at the Mission Site in Toronto from 1978-1991



CO 1-Hour AQC = 30 ppm

Table 10: Summary of Total Reduced Sulphur Levels (ppb) at Station (62030/62052) in Fort Frances, 1982-91

Year	Annual Mean (ppb)	1-Hour Maximum Value (ppb)	No. of 1-Hour Exceedances
1982	8.8	543	685
1983	4.9	254	418
1984	2.8	98	135
1985	2.0	191	87
1986	3.9	226	300
1987	5.5	278	431
1988	5.9	268	552
1989	5.0	126	414
1990	5.5	159	493
1991	4.3	235	251

other factors may contribute significantly to violations of Denver's CO standard. This situation may also occur to some extent at the "Mission" station creating unfavourable dispersion at times when the volume of traffic may be higher, allowing for an earlier accumulation of carbon monoxide. Airflow blocking may also create calm wind conditions local to that area. If measured, windspeeds at this site may in fact be much lower on occasion compared to the meteorological data obtained from the Lawrence/ Kennedy station.

The Yonge Street corridor is descibed by many as an "urban street canyon" which at certain times can lead to high pollutant levels. There are many areas in Toronto which have a similar urban topography and we might expect that these areas would yield higher levels of CO if measured. Although we would expect to witness improvements in air quality for CO due to more efficient and stricter emission controls on vehicles, the increasing number of vehicles on Ontario's roads today works to keep CO emissions relatively steady.

25.4 Case Study 4 - Total Reduced Sulphur (TRS) Odour Problems in Fort Frances

Kraft pulp mills in Ontario are major sources of TRS compounds. Odour levels from these mills significantly impact on the air quality of the surrounding community. Since its construction in the early 1970s, emissions from a bleached kraft pulp mill in Fort Frances have resulted in odour problems in a nearby residential area. In the late 1970s, some emission reductions were achieved. In 1980, a Control Order was issued by the provincial Ministry for further pollution controls. The mill also created a "buffer zone" through the purchase of adjacent residential land.

A summary of the TRS levels at the main monitoring site in Fort Frances is provided in Table 10. In this table, the annual mean, 1-hour maximum and number of exceedances of the 1-hour TRS AQC of 27 ppb are listed for the last ten years. The air quality improvement apparent for 1984 and 1985 was due inpart to the use of monitors which under estimated TRS levels at that time.

In 1991, the monitoring site (62030) in Fort Frances recorded its lowest annual mean (4.3 ppb) over the last five years and also the fewest number of 1-hour exceedances (251) over the past six years. This achievement is attributed to ongoing abatement programs at the Fort Frances mill.

Several communities in Ontario (in addition to Fort Frances) experience air quality problems due to odours from nearby kraft pulp mills. Cornwall, Thorold, Terrace Bay, Thunder Bay, Smooth Rock Falls, Red Rock and Marathon are additional examples.

It should also be noted that, on occasion, TRS 1-hour exceedances have also been recorded in Windsor, Hamilton, Oakville, Mississauga and Sault Ste. Marie. Exceedances in these locations are usually due to iron and steel or refinery operations.

Section G - Meteorology and Air Quality

Weather conditions play a major role in the levels of air pollution. Weather factors which affect air pollutant concentrations are:

- wind, which transports and disperses pollutants emitted from sources,
- temperature, which affects the amount of fuel used and the dispersion and chemical reactions of pollutants in the atmosphere,
- slow moving high pressure systems, which allow pollutant concentrations to build up in the atmosphere,
- rainfall, which may remove (washout) pollutants from the atmosphere, and
- sunshine, which causes photochemical reactions of air pollutants which form smog.

26.0 Summary of Meteorological Conditions (1991)

The annual mean temperature for 1991 at the majority of locations across Ontario was above normal as daytime maximum temperatures approached the unseasonably hot 30s in April. Summer arrived one month earlier than usual, as during May most locations in Southern Ontario from Windsor to Kingston and as far North as Wiarton broke records for the warmest May ever. Toronto City tied their 17.0°C record mean of 1975, as the warmest May in 151 years. Warm daytime and relatively warm nighttime temperatures in Central Ontario produced the highest May mean temperatures since 1982, and in the north and northwest the warmest since 1986.

Table 11: Number of Days Max Temperature > 30°C (1988-1991)

Station Names	1988	1989	1990	1991
Windsor	52	18	13	41
Sudbury	21	10	0	14
North Bay	9	4	3	3
Ottawa	23	17	15	22
Kingston	12	2	2	6
Toronto	38	12	9	21
Peterborough	31	10	2	19
Thunder Bay	15	8	3	11
Kitchener	29	10	2	11
London	30	7	1	16

Along with the heat, thundershowers kept most of Ontario moist. Windsor recorded 148mm of rain which is twice the normal for May. Normally Southern Ontario records 3 to 4 thunderstorm days during May, but during 1991 a total of 7 occurred; the most since May 1965 when 8 thunderstorm days were recorded. Since 1985, six of the seven Mays have been warmer than the 1951-1980 normal.

Southern Ontario reached new records for the hot and dry June. Monthly mean temperatures were almost 4° warmer than normal with the highest daily maximum of 34.9°C recorded at Ottawa on June 28th.

All regions except the northeast were extremely dry with sunshine measuring 40 to 60 hours above normal across the province.

During July a mid-month heat wave (the most intense in Ontario since the summer of 1988) was mainly responsible for the monthly mean temperatures to be pushed above normal at the majority of Ontario weather stations. However, in comparison to the hot summer of 1987 and 1988, July 1991 was more comfortable, as the mean temperature was only one-half to one degree above normal.

September signalled the return of cooler weather to Ontario as the first below average monthly mean temperatures were recorded for 1991, with most weather stations recording the coolest September since 1984. Thunder Bay and Windsor ranked the coolest since 1975. Table 11 shows the number of hot days (days with maximum temperatures greater than or equal to 30°C) recorded at various temperature recording sites across Ontario for the summers of 1988-1991. In this table it is seen that 1991 recorded more "hot days" across the province than in 1989 and 1990 but less than those recorded during 1988.

Annual wind roses are presented in Figure 45 for selected meteorological sites across Ontario. The entire meteorological network is outlined in Table A-5 and Maps 6 & 7.

27.0 Discussion of Ozone Episodes

Ozone exceedances are confined primarily to the summer months and are strongly influenced by meteorological conditions, particularly large slow moving high pres-

Table 12: Duration of Elevated Ozone Episodes (1988-1991)

	Episode Duration in Days						
Year	1	2	3	4	5	6	7
1988	5	3	0	2	2	0	1
1989	2	4	1	1	0	0	0
1990	8	1	1	0	0	0	0
1991	8	3	1	1	2	0	0
Total	23	11	3	4	4	0	1

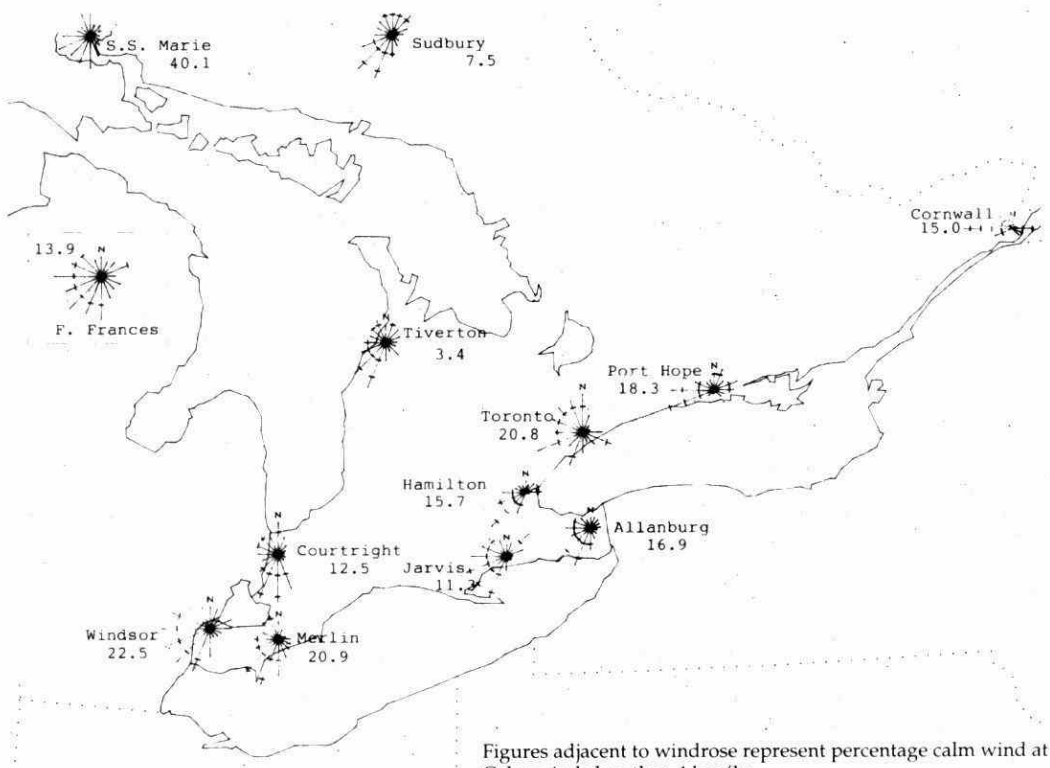
Table 13: Number of Elevated Ozone "Episode Days" in Southern Ontario (1988-1991)

Year	April	May	June	July	August	Sept.	Total
1988	0	7	8	12	9	0	36
1989	0	0	6	8	3	0	17
1990	1	0	2	5	5	0	13
1991	0	7	7	7	7	3	31
Total	1	14	23	32	24	3	97

sure systems. Elevated ozone levels which tend to cover large regions of eastern North America (including southern Ontario) are found typically on the rear sides of high pressure systems or in the warm sectors of low pressure systems. "Ozone episodes" and their relationship to meteorological conditions are analyzed. "Episode-days" are defined as days on which widespread (hundred of kilometres) elevated ozone levels (greater than 80 ppb maximum hourly ground level concentration) occur on the same day at eight or more monitoring sites. "Episodes" are defined as distinct events associated with episode days. There were 31 episode days during 1991 compared to 36 in 1988, 17 in 1989 and 13 in 1990 respectively. Exceedances during 1991 were approximately half the number of those recorded during the hot dry summer of 1988 but were twice the number recorded during the summer of 1990. Table 11 shows that the 1991 summer recorded substantially more hot days recording maximum temperatures greater than or equal to 30°C than 1989 and 1990. As a result the ozone AQC was exceeded on many more occasions than in 1989 and 1990.

The number and duration of ozone episode days that were recorded in Ontario, since the start up of the Air Quality Index system in 1988 are shown in Tables 12

Figure 45: Annual Wind Roses for Selected Meteorological Sites Across Ontario



Figures adjacent to windrose represent percentage calm wind at that site.
Calm winds less than 4 km/hr.
1 Division = 5% of time.

and 13. Note that on the average the majority of the episodes occur during the months of June, July and August. During the period 1988-1991, the longest episode was 7 days (July 1988). In 1988 and 1991 there were two five day episodes. Such long episodes occur with stagnant or slow moving high pressure systems centered south of the lower Great Lakes, coupled with high pressure aloft (upper atmosphere) thus resulting in a deep stagnant warm high pressure system. The resultant clear skies and dry conditions are conducive to increased photochemical activity of the lower troposphere.

With the high centered south of the lower Great Lakes, a southwesterly flow is set up advecting ozone and its precursors into southern Ontario. This synoptic transport appears to be the primary cause of elevated ozone levels in southern Ontario during the summer months.

Episode July 16-20, 1991

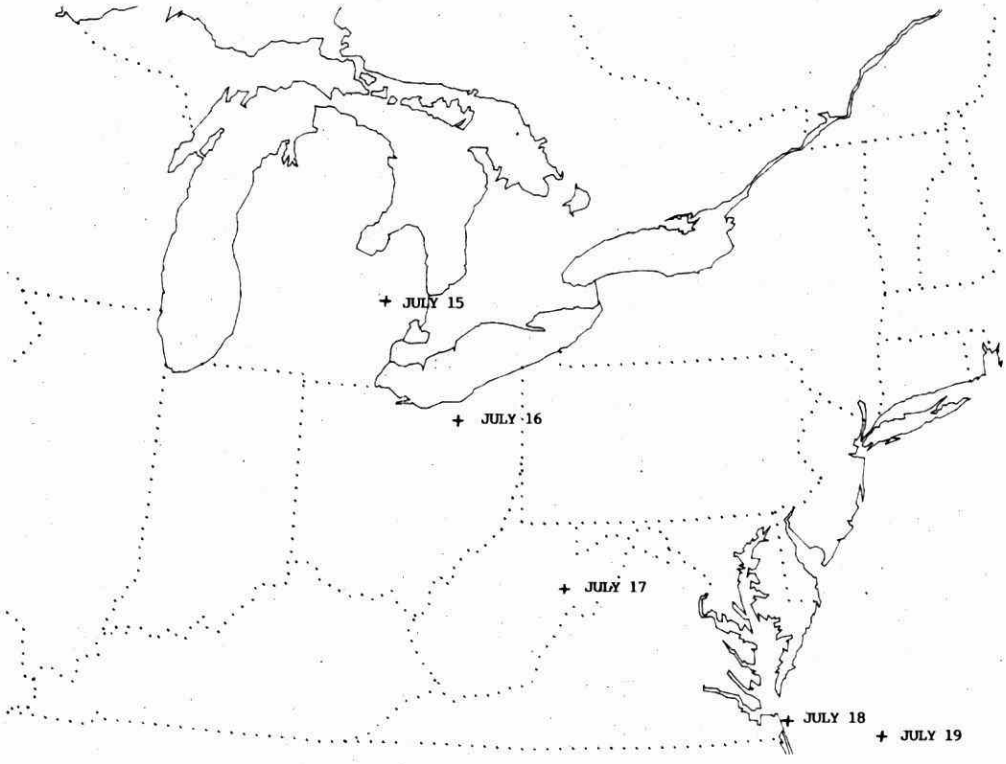
The episode of July 16-20, 1991 is analysed to demonstrate some of the points discussed above. During three days of this episode at least 30 of the 42 ground level ozone monitoring sites recorded elevated levels (>80 ppb) of ozone.

At 0700 EST on July 15, an area of high pressure centered over north-eastern Michigan tracked south-southeastward to lie just south of Lake Erie at 0700 EST on July 16 (Figure 46). The high pressure continued to track south-southeastward and then became stationary over the eastern seaboard of the U.S. by 0700 EST on July 18.

With the high pressure area centered south of the Lower Great Lakes, a persistent west/southwesterly flow into southern Ontario developed. Daily maximum temperatures in the 30s (Figure 47) and more than 12 hours of daily bright sunshine (Figure 48) helped to contribute towards the high ozone levels. Figure 49 shows 48-hour back air trajectories from Toronto at 1900 EST from July 15 to 20 and Figures 50 and 51 show the daily distribution of maximum ozone concentrations recorded at various monitoring sites across Ontario on July 15 and 16.

On July 15 when the flow was from northern Ontario, only one site in Ontario, Windsor University (12016), exceeded the 80 ppb 1-hour Ontario AQC. The higher ozone levels recorded in Windsor are influenced by percursor emissions from the Sarnia area as the 48- hour back trajectory ending at 2100 EST at Windsor (Figure 52) shows that the airmass had passed over Sarnia before arriving at Windsor. Also the back trajectory shows that the airmass stagnated over the Windsor-Detroit area on July 15. A combination of percursors from Sarnia and

Figure 46: Position of the Centre of High Pressure System at 0700 EST from July 15-19, 1991



Windsor-Detroit contributed to the high ozone levels.

By July 16 a persistent west-south-westerly flow into southern Ontario was established and most of the sites recorded ozone concentrations above the 1-hour AQC.

On July 18 the majority of sites in southern Ontario recorded levels less than their maximum of the previous day. This was due to the fact that the air parcel, based on the 48-hour back trajectory, originated over the Wisconsin/Illinois border where fewer industries are located than in Central Illinois where the air mass originated on the previous days. The west-southwesterly flow continued until the morning of Sunday, July 21 when a cold front passed through southern Ontario.

On Monday, July 15, with a northerly flow, the maximum ozone concentration recorded at Simcoe was 45 ppb. The maximum on Tuesday July 16, was 93 ppb. This indicates that between July 15 and 16 there was an increase in concentration of 48 ppb. For this near border site, U.S. emissions are likely responsible for most of the increase in ozone. At Tiverton the maximum ozone concentration increased from 46 ppb on July 15 to 106 ppb on July 16. Emissions of NO_x and VOC, precursors of ozone, from the mid U.S. and Windsor-Sarnia areas contributed to the increase in ozone at this site.

Figure (48) shows that the air parcels originated over Illinois and not over the Ohio Valley which is normal for episodes that develop on the rear of the high pressure system. However, like the Ohio Valley, Illinois and Michigan are relatively high ozone precursor source areas.

Occupational Health and Safety

Ozone was recognized as a powerful lung irritant soon after its initial synthesis in 1851. It was placed on the American Conference of Government Industrial Hygienists (ACGIH) of threshold limit values (TLVs) for occupational exposure in 1954, with an 8-hour time weighted concentration limit of 100 ppb, and a short term exposure limit of 300 ppb. These limits were based on the provision of protection of the worker from the acute irritant effects of ozone, possible longer term respiratory effects and premature aging, particularly of the elastic tissues of the respiratory tissues. In 1989 the ACGIH revised the exposure limits for ozone by dropping the time weighted average limit and introducing a ceiling limit of 100 ppb. The rationale behind this at the time was that ozone caused acute effects but not cumulative effects and the revised limit provided workers, including asthmatics, with protection against these effects. Since 1989 however several studies have reported cumulative effects on the repiratory system following several hours of exposure and the question of reintroducing a longer term limit is likely to re-emerge.

In Ontario, the time weighted average exposure value (TWAEV) is 100 ppb with a 15 minute short term exposure value (STEV) of 300 ppb.

Tables 14 and 15 show for the period 1988 to 1991, the number of days and hours respectively when the 8-hour running average of ground level ozone concentration, at the various monitoring sites across Ontario, was greater than or equal to 100 ppb.

Most exceedances occurred at rural sites, particularly at sites nearest the industrial States south of the Lower Great Lakes (e.g. Long Point and Tiverton). There were more exceedances of the 8-hour criterion at rural sites because of less scav-

Figure 47:
Daily Maximum Temperature as Recorded Across Ontario from July 16-20, 1991

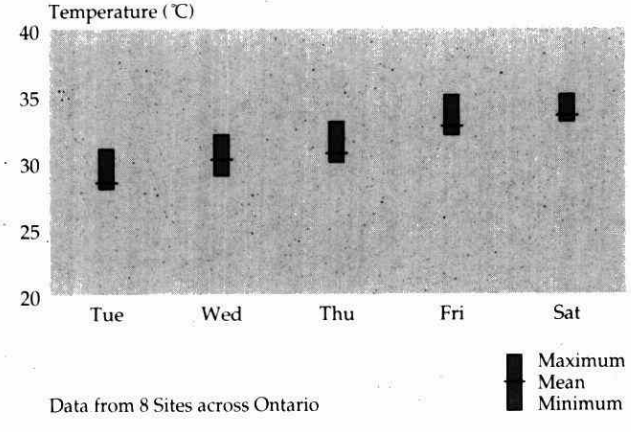


Figure 48:
Hours of Bright Sunshine as Recorded Across Ontario from July 15-21, 1991

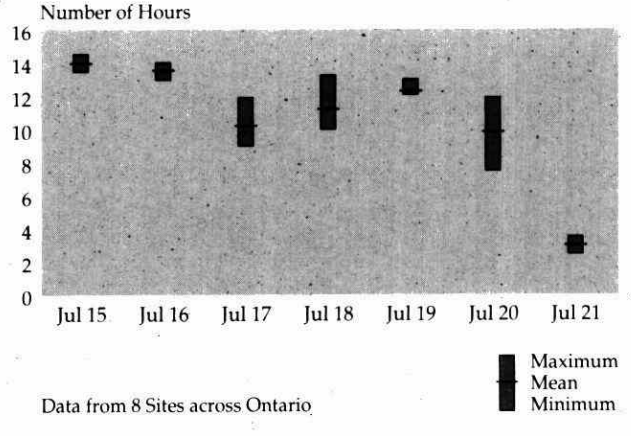
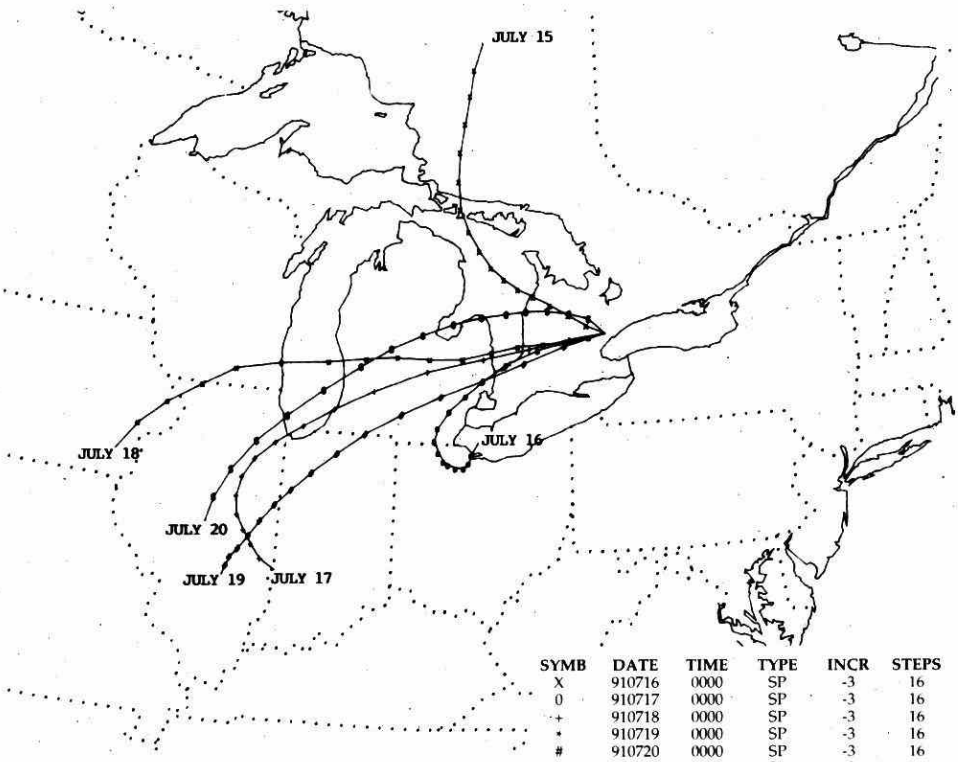


Figure 49: 48-Hour Back Trajectories for Toronto, Ending Daily at 1900 EST, During the Period of July 16-20, 1991



SYMB	DATE	TIME	TYPE	INCR	STEPS	RES	ANSC	VELC
X	910716	0000	SP	-3	16	127.0	15.	.90
0	910717	0000	SP	-3	16	127.0	15.	.90
+	910718	0000	SP	-3	16	127.0	15.	.90
*	910719	0000	SP	-3	16	127.0	15.	.90
#	910720	0000	SP	-3	16	127.0	15.	.90
$	910721	0000	SP	-3	16	127.0	15.	.90

Figure 50: Distribution of Maximum Ozone Concentrations (ppb) at Sites Across Ontario on July 15, 1991

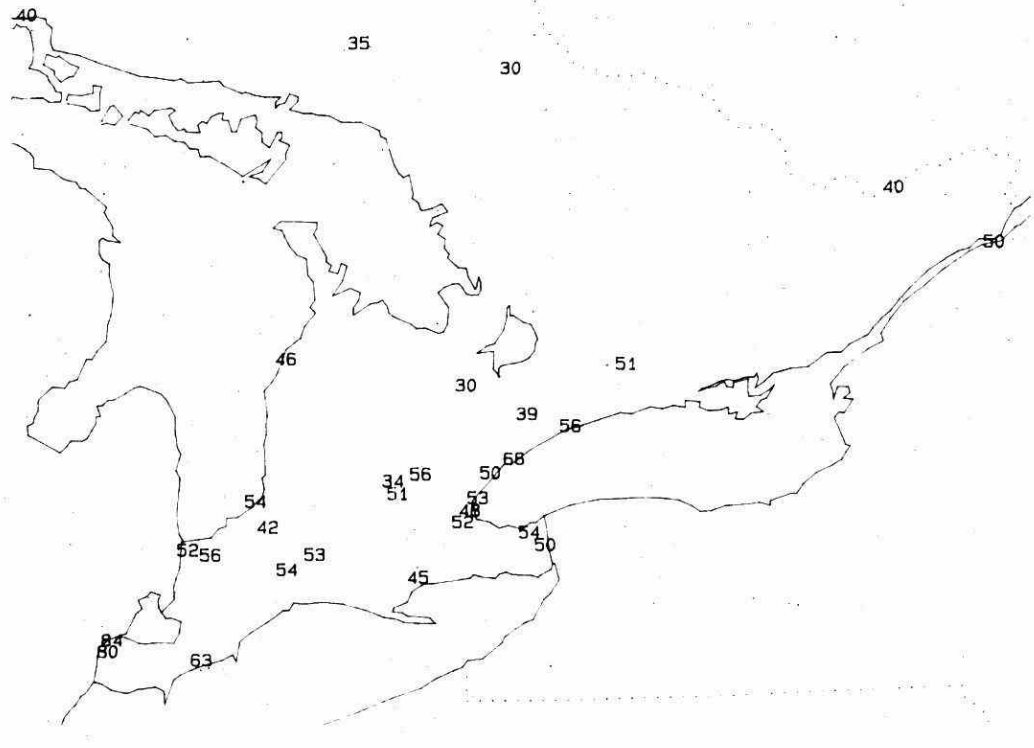


Figure 51: Distribution of Maximum Ozone Concentrations (ppb) at Sites Across Ontario on July 16, 1991

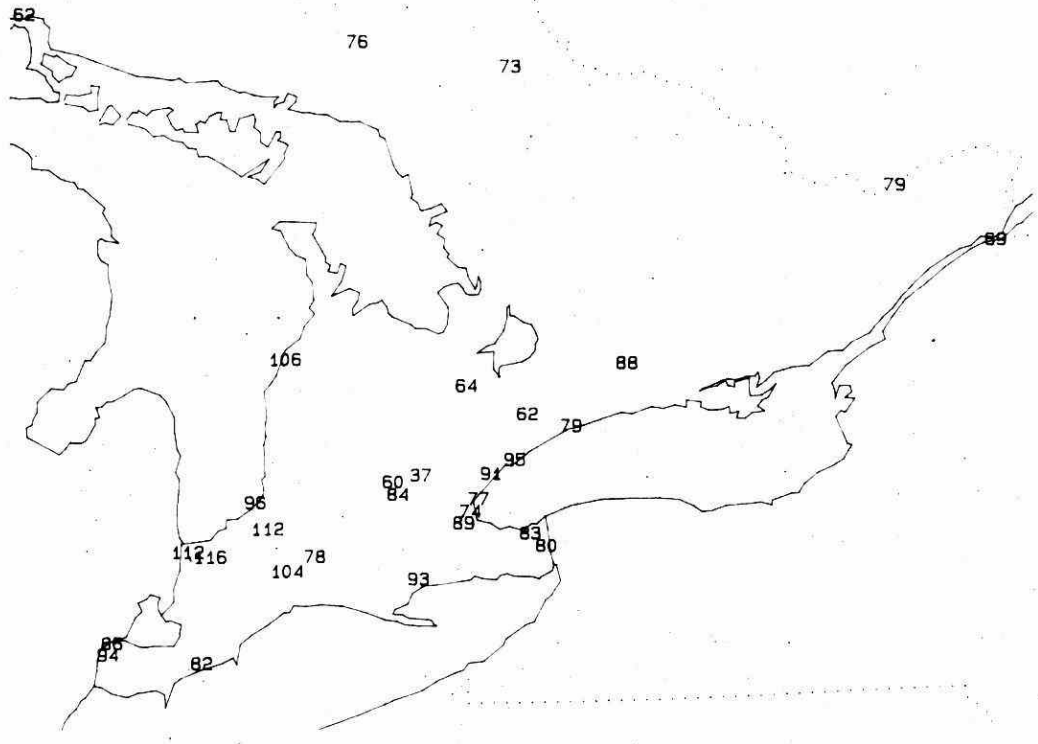


Figure 52: 48-Hour Back Trajectory for Windsor Ending at 2100 EST on July 15, 1991

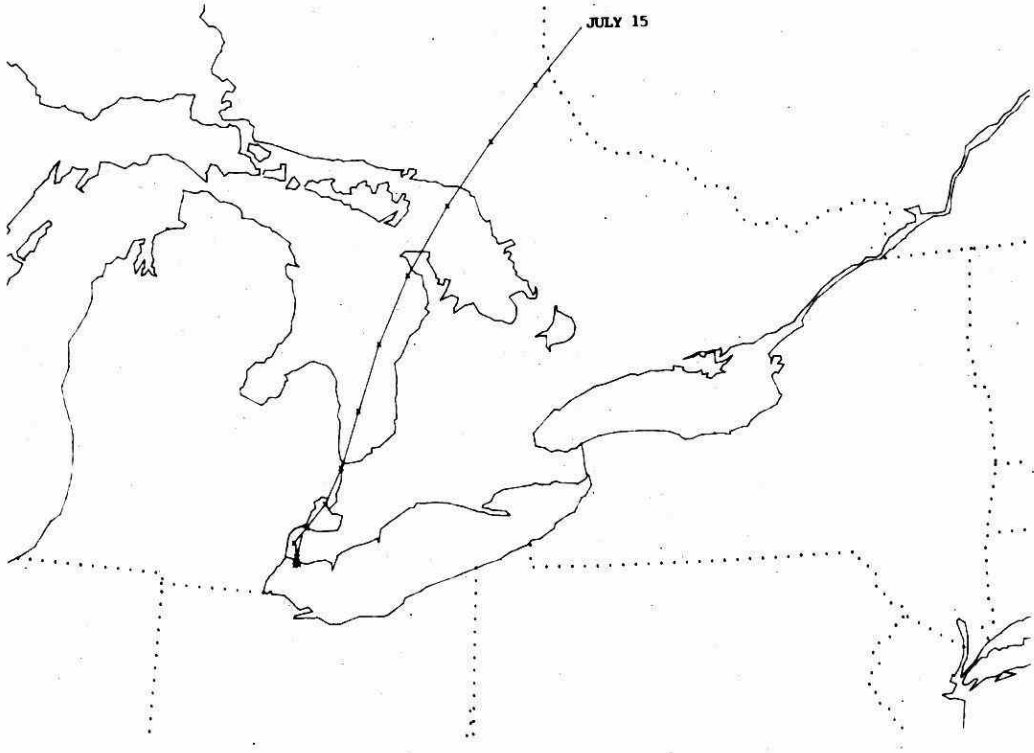
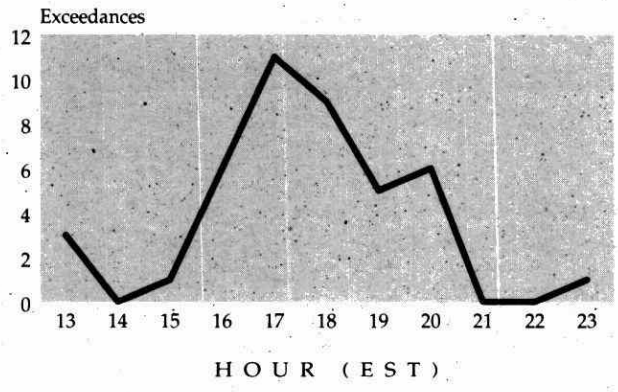


Figure 53:
Frequency of the Initial Starting Time of Exceedances of the Ozone 8-Hour Running Mean



enging of ozone in rural areas compared to urban areas; less deposition of ozone over lake surfaces compared to land surfaces and an increase in the photochemical production of ozone in the air mass downwind of urban centres. During the hot dry summer of 1988 only six of the ozone monitoring sites did not exceed the 8-hour 100 ppb criterion on at least one day. Four of these sites are located in northern Ontario.

Figure 53 shows the frequency distribution of the hours that the 8-hour running average criterion was exceeded at the sites across southern Ontario during 1991. The majority of exceedances occurred between 1600 to 2000 EST, thus outdoor workers who continue to work after 1600 EST, on days when the 8-hour criterion is exceeded, could be affected. Table 16 shows some statistics for sites that exceeded the 8-hour criterion during 1991. Tiverton, a rural site, recorded the highest maximum 8-hour average concentration of 139 ppb on June 27. In the Greater Metropolitan Toronto area, the North York Central site, recorded the highest maximum 8-hour average concentration of 109 ppb on July 20.

Table 14: No of Days 8-Hour Running Mean ≥ 100ppb at Various Ozone Monitoring Sites (1988-1991)

Station	Name	1988	1989	1990	1991
10001	Huron Park	5	0	1	0
12008	Windsor University	6	1	0	0
12016	Windsor College	9	1	0	3
13021	Merlin	15	0	0	2
14064	Sarnia	2	1	1	1
14118	Mandaumin	5	2	1	2
15001	London	5	0	1	0
15009	Longwoods	1	4	0	2
15013	Parkhill	4	0	0	5
18007	Tiverton	13	1	2	6
22071	Simcoe	17	0	0	0
22901	Long Point	31	10	5	6
26029	Kitchener	4	0	0	0
26045	Waterloo	0	0	0	1
27056	Niagara Falls	8	0	0	0
27067	St. Catharines	2	0	0	0
28028	Guelph	2	0	0	0
29000	Hamilton-Downtown	4	1	0	0
29105	Hamilton-East	3	0	0	2
29114	Hamilton-Mountain	2	0	1	0
29118	Hamilton-West	6	0	2	0
31104	Toronto-Downtown	1	0	1	0
31120	Toronto-West	4	2	0	1
31190	Toronto-Cn Tower	14	7	0	6
32010	East York	0	0	0	0
33003	Scarborough	2	1	0	0
34020	North York Central	4	0	0	1
34025	North York West	4	0	0	0
35003	Etobicoke-West	5	1	0	0
35033	Etobicoke-South	1	0	0	0
36030	York	6	0	0	1
44008	Burlington	1	4	0	1
44015	Oakville	6	2	0	0
45025	Oshawa	4	3	1	1
46110	Mississauga	2	4	0	0
47035	Alliston	3	0	0	0
48002	Stouffville	4	3	0	1
51001	Ottawa	3	0	0	0
52020	Kingston	5	1	0	1
56051	Cornwall	3	0	1	0
59006	Peterborough	2	0	0	0
63100	Hawkeye Lake	0	0	0	0
63200	Thunder Bay	0	0	0	0
71068	Sault Ste Marie	0	0	0	0
75010	North Bay	1	0	0	0
77203	Sudbury	0	0	0	0

Note: Station 26029 was changed to 26060 in May 1990
Station 31104 was changed to 31103 in October 1990

Table 15: Number of Hours 8-Hour Running Mean ≥ 100ppb at Ozone Monitoring Sites Across Ontario (1988-1991)

Station	Name	1988	1989	1990	1991
10001	Huron Park	23	0	2	0
12008	Windsor University	34	3	0	0
12016	Windsor College	43	1	0	6
13021	Merlin	63	0	0	7
14064	Sarnia	5	9	0	1
14118	Mandaumin	20	3	2	8
15001	London	15	0	1	0
15009	Longwoods	5	20	0	11
15013	Parkhill	20	0	0	19
18007	Tiverton	64	5	9	36
22071	Simcoe	91	0	0	0
22901	Long Point	271	60	17	21
26029	Kitchener	12	0	0	0
26045	Waterloo	0	0	0	1
27056	Niagara Falls	41	0	0	0
27067	St. Catharines	9	0	0	0
28028	Guelph	8	0	0	0
29000	Hamilton-Downtown	14	5	0	0
29105	Hamilton-East	9	0	3	11
29114	Hamilton-Mountain	11	0	9	0
29118	Hamilton-West	27	0	4	0
31104	Toronto-Downtown	7	0	0	0
31120	Toronto-West	14	4	0	4
31190	Toronto-Cn Tower	147	36	0	37
32010	East York	0	0	0	0
33003	Scarborough	8	6	0	0
34020	North York Central	22	0	0	5
34025	North York West	8	0	0	0
35003	Etobicoke-West	13	4	0	0
35033	Etobicoke-South	3	0	0	0
36030	York	22	0	0	4
44008	Burlington	5	13	0	4
44015	Oakville	25	7	5	0
45025	Oshawa	12	9	0	2
46110	Mississauga	10	16	0	0
47035	Alliston	11	0	0	0
48002	Stouffville	17	14	0	5
51001	Ottawa	17	0	0	0
52020	Kingston	25	3	5	5
56051	Cornwall	14	0	0	0
59006	Peterborough	5	0	0	0
63100	Hawkeye Lake	0	0	0	0
63200	Thunder Bay	0	0	0	0
71068	Sault Ste Marie	0	0	0	0
75010	North Bay	2	0	0	0
77203	Sudbury	0	0	0	0

Note: Station 26029 was changed to 26060 in May 1990
Station 31104 was changed to 31103 in October 1990

Table 16: 8-Hour Running Mean Statistics for Sites That Exceeded 8-Hour Ozone Concentration ≥ 100 ppb During 1991

Station	Name	# of Days	Max. Duration (Hrs)*	Date of Max.	Max. 8-Hr. Avg. Concentration (ppb)
12o16	Windsor College	3	3	20/6	103
13o21	Merlin	2	6	22/5	108
14o64	Sarnia	1	1	21/5	103
14118	Mandaumin	2	6	19/7	111
15oo9	Longwoods	2	7	19/7	115
15o13	Parkhill	5	8	19/7	115
18oo7	Tiverton	6	8	27/6	139
229o1	Long Point	6	11	16/5	119
26o6o	Kitchener	1	1	21/6	100
291o5	Hamilton-East	2	6	10/6	104
3112o	Toronto-West	1	4	20/7	107
3119o	Toronto-Cn Tower	6	7	22/5	116
34o2o	North York Central	1	5	20/7	109
36o3o	York	1	4	20/7	106
44oo8	Burlington	1	4	29/8	113
45o25	Oshawa	1	2	20/7	105
48oo2	Stouffville	1	5	22/5	107
52o2o	Kingston	1	5	19/7	103

* Maximum number of hours that the 8-hour running average was greater than or equal to 100 ppb

Table 8a: 10-Year Trend for SO_2 Annual Mean (ppm)

City	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Burlington	0.005	0.005	0.005	0.004	0.004	0.004	0.004	0.007	0.006	0.003
Cornwall	0.010	0.008	0.009	0.009	0.008	0.006	0.006	0.007	0.005	0.005
Etobicoke	0.006	0.006	0.007	0.007	0.005	0.005	0.006	0.005	0.006	0.006
Hamilton	0.014	0.014	0.015	0.009	0.008	0.007	0.008	0.010	0.007	0.007
Kitchener	0.003	0.002	0.003	0.002	0.003	0.004	0.003	0.003		0.003
London	0.004	0.003	0.004	0.002	0.003	0.003	0.004	0.006	0.004	0.005
Long Point	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.004	0.004
Mississauga	0.006	0.006	0.006	0.006	0.007	0.009	0.004	0.004	0.004	0.005
Niagara Falls	0.003	0.003	0.004	0.003	0.003	0.002	0.005	0.005	0.005	0.005
North Bay	0.003	0.002	0.003	0.002	0.002	0.002	0.002	0.002	0.001	0.001
North York	0.012	0.006	0.009	0.008	0.005	0.002	0.002	0.002	0.002	0.002
Oakville	0.007	0.005	0.007	0.006	0.005	0.003	0.005	0.006	0.005	0.005
Oshawa	0.004	0.003	0.005	0.003	0.003	0.004	0.006	0.006	0.004	0.004
Ottawa	0.004	0.002	0.002	0.002	0.002	0.001	0.002	0.003	0.002	0.003
Peterborough	0.003	0.002	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.003
Sarnia	0.012	0.010	0.009	0.011	0.008	0.007	0.009	0.008	0.012	0.009
Scarborough	0.004	0.003	0.004	0.003	0.003	0.004	0.008	0.006	0.006	0.004
Simcoe	0.004	0.003	0.004	0.005	0.003	0.003	0.005	0.005	0.004	0.003
St Catharines	0.005	0.005	0.005	0.006	0.005	0.010	0.011	0.006	0.004	0.005
Stouffville	0.003	0.005	0.005	0.004	0.002	0.002	0.003	0.004	0.003	0.004
Sudbury	0.010	0.009	0.010	0.010	0.008	0.009	0.010	0.008	0.008	0.005
Thunder Bay	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Tiverton	0.001	0.003	0.007	0.002	0.001	0.001	0.003	0.002	0.001	0.001
Toronto	0.006	0.004	0.006	0.004	0.004	0.004	0.007	0.008	0.006	0.005
Windsor	0.009	0.008	0.007	0.007	0.008	0.008	0.011	0.008	0.007	0.007
Provincial Mean	0.006	0.005	0.006	0.005	0.004	0.004	0.005	0.005	0.005	0.004

Table 8b: 10-Year Trend for CO Annual Mean (ppm)

City	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Cornwall	1.0	0.2	0.2	0.2	0.2	0.3	0.6	0.8	0.6	0.8
Etobicoke	1.1	1.6	1.4	1.3	1.2	1.2	1.2	0.7	0.8	0.8
Hamilton	1.1	0.9	0.8	1.2	1.1	1.2	1.2	1.2	1.2	1.1
Kitchener	1.0	1.0	0.9	0.8	0.9	0.8	0.9	1.1		0.6
London	0.3	0.3	0.4	0.3	0.3	0.4	0.5	0.9	0.6	0.7
Mississauga	1.5	1.4	1.4	1.9	1.4	1.3	1.0	1.1	1.1	1.1
North York	2.3		1.3	1.4	1.3	1.2	0.8	0.8	1.0	0.7
Oakville	1.4	1.3	0.9	1.0	1.0	0.8	0.9	0.9	0.5	0.5
Oshawa	1.9	2.0	1.8	1.0	1.2	0.8	1.1	0.9	0.9	0.8
Ottawa	0.9	0.2	0.3	0.6	0.6	0.3	0.5	0.7	0.7	1.0
Sarnia	0.2	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.2
Scarborough	1.6	1.2	1.4	1.3	1.0	1.1	1.0	1.2	1.2	1.0
St Catharines	0.4	0.4	0.4	0.2	0.2		1.0	0.9	1.0	0.7
Sudbury	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.4	0.5	0.3
Toronto	1.5	1.1	1.0	1.1	1.0	1.1	0.6	0.9	1.1	1.1
Windsor	0.5	0.8	0.5	0.5	0.5	0.7	0.9	1.0	1.2	1.0
Provincial Mean	1.1	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.8	0.8

Table 8c: 10-Year Trend for NO_2 Annual Mean (ppm)

City	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Cornwall	0.010	0.011	0.011	0.010	0.011	0.010	0.008	0.009	0.008	0.006
Etobicoke	0.021	0.021	0.024	0.026	0.027	0.028	0.021	0.030	0.026	0.025
Hamilton	0.031	0.029	0.029	0.025	0.027	0.026	0.024	0.026	0.022	0.022
Kitchener	0.028	0.025	0.027	0.029	0.032	0.026	0.027	0.025		0.013
London	0.021	0.021	0.024	0.025	0.026	0.021	0.020	0.022	0.021	0.019
Mississauga	0.026	0.026	0.026	0.026	0.026	0.025	0.021	0.025	0.020	0.022
North York	0.022	0.023	0.026	0.027	0.023	0.025	0.027	0.028	0.028	0.029
Oakville	0.018	0.016	0.018	0.016	0.020	0.017	0.016	0.016	0.017	0.017
Oshawa	0.020	0.019	0.021	0.020	0.021	0.022	0.024	0.024	0.019	0.018
Ottawa	0.015	0.014	0.014	0.012	0.012	0.015	0.016	0.017	0.016	0.020
Sarnia	0.022	0.020	0.023	0.019	0.021	0.012	0.015	0.019	0.021	0.019
Scarborough	0.025	0.019	0.018	0.018	0.022	0.022	0.025	0.027	0.025	0.024
Simcoe	0.010	0.009	0.009	0.006	0.005	0.005	0.008	0.010	0.005	0.007
St Catharines	0.019	0.020	0.018	0.017	0.019		0.018	0.021	0.016	0.016
Sudbury	0.006	0.006	0.006	0.007	0.010	0.011	0.010	0.011	0.009	0.009
Toronto	0.027	0.025	0.027	0.026	0.027	0.025	0.025	0.027	0.025	0.029
Windsor	0.029	0.026	0.027	0.026	0.025	0.027	0.030	0.027	0.025	0.025
Provincial Mean	0.021	0.019	0.020	0.020	0.021	0.020	0.020	0.021	0.019	0.019

Table 8d: 10-Year Trend for NO Annual Mean (ppm)

City	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Cornwall	0.005	0.008	0.007	0.008	0.005	0.011	0.010	0.009	0.008	0.006
Etobicoke	0.027	0.026	0.026	0.027	0.031	0.028	0.026	0.029	0.023	0.019
Hamilton	0.024	0.018	0.023	0.019	0.022	0.014	0.017	0.014	0.012	0.011
Kitchener	0.038	0.045	0.046	0.047	0.051	0.051	0.047	0.045		0.005
London	0.015	0.014	0.017	0.013	0.019	0.018	0.015	0.015	0.016	0.011
Mississauga	0.025	0.027	0.028	0.030	0.032	0.030	0.026	0.024	0.019	0.020
North York	0.036	0.030	0.027	0.028	0.022	0.026	0.021	0.026	0.038	0.020
Oakville	0.015	0.012	0.017	0.016	0.020	0.018	0.036	0.030	0.015	0.011
Oshawa	0.017	0.013	0.023	0.017	0.016	0.019	0.014	0.018	0.020	0.014
Ottawa	0.013	0.009	0.012	0.011	0.010	0.012	0.011	0.012	0.009	0.009
Sarnia	0.009	0.010	0.008	0.007	0.009	0.006	0.006	0.007	0.007	0.006
Scarborough	0.028	0.028	0.033	0.032	0.032	0.035	0.033	0.033	0.027	0.026
Simcoe	0.002	0.002	0.005	0.004	0.007	0.005	0.002	0.001	0.001	0.002
St Catharines	0.008	0.009	0.016	0.009	0.008		0.010	0.011	0.011	0.008
Sudbury	0.007	0.005	0.007	0.010	0.008	0.008	0.005	0.006	0.005	0.005
Toronto	0.022	0.019	0.021	0.019	0.022	0.021	0.018	0.022	0.021	
Windsor	0.011	0.016	0.028	0.015	0.021	0.014	0.014	0.015	0.016	0.019
Provincial Mean	0.018	0.017	0.020	0.018	0.020	0.020	0.018	0.019	0.016	0.012

Table 8e: 10-Year Trend for O_3 Annual Mean (ppb)

City	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Cornwall	21.5	22.7	27.6	25.8	22.8	20.8	24.0	20.4	21.2	20.7
Etobicoke	15.6	15.7	16.5	18.1	16.7	16.0	19.3	16.9	16.4	19.0
Hamilton	16.9	18.7	18.0	19.0	16.4	16.2	17.9	16.7	17.6	19.9
Huron Park	23.4	24.2	26.5	26.5	26.1	25.9	29.7	28.0	27.4	
Kitchener	17.8	18.9	18.3	19.9	17.0	17.1	21.6	19.9		27.2
London	21.3	21.0	19.4	21.3	18.4	19.4	23.7	22.9	22.1	22.7
Long Point	34.1	29.9	31.2	34.4	31.4	31.7	38.4	35.7	33.0	33.9
Mandaumin	22.5	19.1	25.9	27.9	23.1	25.9	30.0	28.4	23.7	28.1
Merlin	25.3	22.6	21.0	22.0	19.8	27.3	31.5	27.2	26.0	28.4
Mississauga	14.2	16.6	15.4	16.0	15.7	14.5	17.7	18.6	17.8	18.6
North York	14.5	18.3	15.5	11.8	7.4	8.9	9.0	12.8	13.3	14.7
Oakville	16.0	18.1	16.7	19.6	18.5	19.8	20.9	22.1	22.2	22.1
Oshawa	18.8	21.1	17.1	18.2	17.2	17.9	20.2	21.9	18.8	22.6
Ottawa	17.1	17.6	17.8	19.2	17.3	16.1	20.7	20.9	21.5	20.8
Sarnia	22.7	23.0	23.3	22.9	20.9	21.8	22.6	25.3	21.4	23.4
Scarborough	14.8	16.7	14.9	13.9	16.6	16.8	17.7	17.9	17.6	19.1
Simcoe	32.3	30.0	28.7	30.6	27.6	28.4	31.2	28.6	26.3	29.1
St Catharines	21.2	23.2	20.3	17.9	21.9		23.6	20.8	23.8	25.0
Stouffville	22.7	20.5	21.0	23.3	20.0	22.9	26.6	28.1	24.9	25.0
Sudbury	16.0	14.2	15.8	13.4	17.1	19.4	29.5	28.9	27.2	27.0
Tiverton	26.8	27.3	27.3	34.6	27.5	33.0	34.6	33.1	31.3	34.2
Toronto	15.3	14.3	16.7	17.1	16.2	15.4	17.5	16.9	15.7	18.0
Windsor	18.1	18.7	18.9	19.7	17.4	17.6	23.5	20.6	17.1	17.6
Provincial Mean	20.4	20.5	20.6	21.4	19.7	20.6	24.0	23.2	22.1	23.5

Table 8f: 10-Year Trend for SP Annual Mean (COH/1000 ft.)

City	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Cornwall	0.16	0.18	0.16	0.09	0.06	0.04	0.10	0.11	0.19	0.17
Etobicoke	0.49	0.37	0.52	0.47	0.54	0.52	0.43	0.32	0.44	0.32
Hamilton	0.57	0.44	0.55	0.52	0.57	0.55	0.46	0.50	0.42	0.41
London	0.32	0.31	0.29	0.30	0.30	0.27	0.25	0.33	0.28	0.25
Niagara Falls	0.22	0.20	0.22	0.20	0.18	0.20	0.32	0.25	0.24	0.20
North York	0.60	0.57	0.62	0.56			0.34	0.41	0.30	0.33
Oshawa	0.41	0.33	0.40	0.37	0.33	0.37	0.31	0.37	0.37	0.35
Ottawa	0.18	0.18	0.19	0.14	0.15	0.19	0.23	0.36	0.35	0.25
Sarnia	0.27	0.27	0.29	0.25	0.31	0.29	0.24	0.30	0.28	0.24
Scarborough	0.37	0.32	0.36	0.34	0.34	0.38	0.37	0.42	0.36	0.34
Sudbury	0.12	0.12	0.15	0.13	0.16	0.16	0.21	0.18	0.12	0.17
St Catharines	0.29	0.27	0.24	0.26	0.24	0.27	0.23	0.25	0.25	0.25
Toronto	0.46	0.41	0.47	0.36	0.39	0.38	0.34	0.37	0.38	0.40
Windsor	0.43	0.47	0.46	0.41	0.43	0.37	0.44	0.40	0.40	0.30
Provincial Mean	0.35	0.32	0.35	0.31	0.31	0.31	0.31	0.33	0.31	0.28

Table 8g: 10-Year Trend for TRS
Annual Mean (ppb)

City	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Cornwall	2.0	3.4	1.5	0.8	2.6	4.3	2.5	3.4	3.4	2.9
Fort Frances	8.8	4.9	2.8	2.0	3.9	5.5	5.9	4.9	5.5	4.3
Hamilton	1.2	1.4	1.8	1.4	1.4	0.9	0.8	0.8	0.9	0.8
Oakville	1.4	1.2	2.8	2.4	2.4	1.6	1.4	1.1	1.3	1.6
Tiverton	0.1	0.1	0.1	0.1	0.1	0.4	0.9	0.4	0	0
Thunder Bay	1.0	0.5	0.6	0.8	1.0	0.8	1.0	1.0	0.2	0.2
Provincial Mean	2.4	1.9	1.6	1.3	1.9	2.3	2.1	1.9	1.9	1.6

Table 8h: 10-Year Trend for TSP
Annual Geometric Mean ($\mu g/m^3$)

City	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Atikokan	20	21	23	23	22	26	27	29		
Bramalea	61	65	66	62	59	63	60	75		39
Burlington	46	49	57	53	45	50	42	56	39	42
Chatham	48	45	41	43	45	51	50	52	43	
Courtright	36	33	37	34	36	34	34	36	30	26
Espanola	45	46	45	42	37	40	37	50	44	45
Etobicoke	55	44	46	51	63	51	43	48	35	46
Fort Frances	32	33	32	26	29	29	26	29	28	25
Hamilton	81	75	81	71	76	77	81	80	69	65
Jarvis	46	46	49	49	44	43	43	52	34	41
Kitchener	54	51	58	46	56	61	62	60		
London	51	52	55	42	50	65	54	57	52	52
Mississauga	62	60	68	55	53	56	54	58	48	44
North Bay	34	33	37	25	29	28	28	28		
North York	43	38	39	40	40	40	47	41*	44	42
Oakville	45	40	47	43	43	45	44	56	48	45
Orillia	59	42	43	42	40	41	64	47		
Oshawa	47	42	44	41	43	51	48	58	47	46
Pickering	48	41	47	49	47	44	52	53		58
Port Colborne	42	51	57	49	54	45	46	51	50	47
Port Hope	36	30	46	45	31	31	30	36		
S.S.Marie	40	35	37	36	34	35	35	33	35	32
Sarnia	58	59	45	46	45	42	42	37	34	34
Scarborough	57	51	60	53	55	53	51	67	48	54
St Catharines	56	68	58	50	60	47	46	55	45	43
St Thomas	55	57	59	56	51	65	54	45	38	34
Sudbury	35	40	34	31	32	35	30	41	42	34
Thunder Bay	39	35	44	36	40	35	37	36	32	33
Toronto	55	54	54	50	51	52	58	60	60	51
Welland	51	49	58	48	42	48	51	48	48	49
Windsor	55	53	57	59	63	68	62	61	60	51
Provincial Mean	48	46	49	45	46	47	46	50	44	43

* change of location from Science Centre (34002) to Yonge/Finch (34020)

Table 8i: 10-Year Trend for Pb in TSP
Annual Geometric mean (μg/m³)

City	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Bramalea	0.30	0.30	0.20	0.20	0.20	0.10	0.04	0.03		0.02
Chatham	0.20	0.20	0.20	0.10	0.10	0.10	0.04	0.02	0.01	
Etobicoke	0.30	0.30	0.20	0.20	0.20	0.10	0.03	0.01	0.01	0.01
Hamilton	0.40	0.40	0.40	0.30	0.30	0.20	0.12	0.09	0.03	0.02
London	0.30	0.30	0.30	0.20	0.10	0.10	0.07	0.04	0.01	0.01
Mississauga	0.30	0.30	0.30	0.20	0.20	0.10	0.03	0.01	0.01	0.01
North Bay	0.20	0.20	0.10	0.10	0.10	0.10	0.02	0.01		
North York	0.30	0.30	0.30	0.20	0.20	0.10		0.01 *	0.01	0.01
Oshawa	0.20	0.20	0.20	0.20	0.10	0.10	0.03	0.01	0.01	0.02
S.S. Marie	0.10	0.20	0.20	0.20	0.10	0.10	0.03	0.03	0.01	0.01
Sarnia	0.10	0.20	0.10	0.10	0.10	0.00	0.03	0.01	0.01	0.01
Scarborough	0.30	0.30	0.40	0.30	0.20	0.10	0.05	0.02	0.01	0.01
Sudbury	0.10	0.10	0.10	0.10	0.10	0.10	0.05	0.03	0.01	0.01
Thunder Bay	0.20	0.20	0.20	0.10	0.10	0.10	0.05	0.03	0.01	0.01
Toronto	0.20	0.30	0.30	0.20	0.20	0.10	0.07	0.04	0.02	0.02
Windsor	0.20	0.20	0.20	0.20	0.20	0.10	0.06	0.03	0.02	0.02
Provincial Mean	0.23	0.25	0.23	0.18	0.16	0.10	0.05	0.03	0.01	0.01

- beginning in 1988 lead reported to two significant digits.
* change of location from Science Centre (34002) to Yonge/Finch (34020)

Table 8j: 10-Year Trend for MN in TSP
Annual geometric mean (μg/m³)

City	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Chatham	0.014	0.012	0.016	0.024	0.011	0.022	0.022	0.022		
Hamilton	0.134	0.128	0.152	0.187	0.175	0.157	0.188	0.199	0.198	0.156
London	0.019	0.026	0.024	0.022	0.018	0.033	0.028	0.033	0.027	0.023
North Bay	0.015	0.007	0.008	0.014	0.008	0.016	0.015	0.017		
Sarnia	0.015	0.022	0.010	0.023	0.014	0.018	0.024	0.011	0.009	0.009
S.S.Marie	0.010	0.032	0.029	0.068	0.040	0.058	0.058	0.062	0.062	0.037
Sudbury	0.006	0.005	0.007	0.016	0.009	0.019	0.017	0.021	0.020	0.014
Thunder Bay	0.010	0.021	0.025	0.043	0.033	0.027	0.021	0.042	0.032	0.029
Toronto	0.024	0.021	0.026	0.032	0.024	0.041	0.040	0.042	0.044	0.040
Windsor	0.033	0.034	0.041	0.055	0.047	0.064	0.057	0.048	0.044	0.030
Provincial Mean	0.028	0.031	0.034	0.048	0.038	0.046	0.047	0.050	0.055	0.042

Table 8k: 10-Year Trend for CU in TSP
Annual geometric mean ($\mu g/m^3$)

City	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Chatham	0.23	0.18	0.10	0.11	0.13	0.15	0.03	0.02		
Hamilton	0.23	0.32	0.30	0.23	0.15	0.15	0.08	0.09	0.06	0.11
London	0.13	0.33	0.21	0.16	0.13	0.28	0.07	0.03	0.03	0.02
North Bay	0.38	0.22	0.20	0.15	0.13	0.18	0.11	0.12		
S.S.Marie	0.13	0.26	0.14	0.16	0.14	0.12	0.06	0.09	0.07	0.14
Sudbury	0.23	0.22	0.27	0.15	0.24	0.17	0.10	0.18	0.14	0.15
Thunder Bay	0.08	0.18	0.19	0.19	0.07	0.06	0.04	0.05	0.03	0.03
Toronto	0.12	0.16	0.15	0.12	0.11	0.12	0.10	0.08	0.09	0.08
Windsor	0.10	0.16	0.09	0.09	0.10	0.13	0.05	0.03	0.04	0.02
Provincial Mean	0.18	0.23	0.18	0.15	0.13	0.15	0.07	0.08	0.07	0.08

Table 8l: 10-Year Trend for FE in TSP
Annual geometric mean ($\mu g/m^3$)

City	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Chatham	0.6	0.7	0.5	0.6	0.5	0.7	0.6	0.5		
Hamilton	2.5	2.2	2.3	1.9	2.6	2.5	2.7	2.4	2.2	1.9
Kitchener	0.5	0.7	0.6	0.6	0.5	0.6	0.8	0.5		
London	0.5	0.6	0.6	0.5	0.5	0.8	0.7	0.6	0.5	0.5
North Bay	0.5	0.2	0.3	0.3	0.3	0.4	0.4	0.4		
Sarnia	0.5	0.5	0.4	0.5	0.4	0.4	0.5	0.3	0.3	0.3
S.S.Marie	0.5	0.5	0.7	1.2	0.6	1.1	0.9	1.1	0.9	0.8
Sudbury	0.7	0.9	0.8	0.7	0.6	0.8	0.8	0.7	0.8	0.7
Thunder Bay	1.0	0.9	1.2	0.8	1.0		1.0	1.0	0.8	0.7
Toronto	0.7	0.8	0.8	0.7	0.6	0.8	0.9	0.7	0.9	0.8
Windsor	1.2	1.2	1.5	1.5	1.9	2.1	1.9	1.4	1.1	0.9
Provincial Mean	0.8	0.8	0.9	0.8	0.9	1.0	1.0	0.9	0.9	0.8

Table 8m: 10-Year Trend for NO_3 in TSP
Annual geometric mean ($\mu g/m^3$)

City	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Bramalea	4.3	3.8	3.8	3.6	3.7	3.3	4.0	3.8		
Etobicoke	4.9	3.3	3.7	3.0	3.8	2.8	3.1	3.6		
Hamilton	3.7	3.7	3.8	3.5	3.8	3.9	3.7	4.7	3.3	4.5
Kitchener	3.7	3.1	3.3	2.8	3.3	3.2	1.8	4.2		
London	3.6	3.3	3.6	3.3	3.6	3.9	2.3	3.9		
Mississauga	4.0	4.1	3.8	3.5	3.0	2.9	1.8	2.6		
North Bay	1.2	1.2	1.1	1.0	0.9	0.9	1.3	1.5		
North York	3.2	3.1	3.3	3.1	2.7	2.8	2.9	3.1*		
Oshawa	3.2	3.0	3.5	2.9	3.0	3.2	2.1	3.5		
Port Hope	4.2	2.3	4.3	3.0	1.7	2.8	2.5	2.8		
S.S.Marie	1.2	1.3	1.2	1.0	0.9	0.9	1.4	1.2	0.8	1.5
Scarborough	3.3	3.2	3.6	3.2	3.1	2.8	1.9	3.7		
Sudbury	1.4	1.5	1.0	0.8	0.6	1.3	0.8	1.2	1.2	1.3
Thunder Bay	1.2	0.7	0.9	0.8	0.9	1.0	1.1	1.3	1.1	1.5
Toronto	3.8	3.6	3.5	3.5	3.4	3.3	3.1	4.2		3.4
Windsor	3.7	3.4	3.7	3.9	4.3	5.2	4.0	5.1	5.5	4.1
Provincial Mean	3.2	2.8	3.0	2.7	2.7	2.8	2.4	3.2	2.4	2.7

* change of location from Science Centre (34002) to Yonge/Finch (34020)

Table 8n: 10-Year Trend for SO_4 in TSP
Annual geometric mean ($\mu g/m^3$)

City	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Bramalea	8.8	9.0	10.8	7.7	8.8	7.7	9.7	8.2		
Etobicoke	11.3	8.8	9.3	7.7	8.7	8.2	8.4	8.3		10.2
Hamilton	9.6	10.1	10.9	8.8	11.5	13.0	10.9	11.7	11.0	11.2
Kitchener	8.5	7.0	7.7	5.7	7.6	9.8	5.8	9.1		
London	7.9	7.3	8.7	6.9	7.5	9.4	5.9	8.0		
Mississauga	9.5	10.0	10.7	7.1	7.1	9.2	6.1	6.1		
North Bay	6.3	6.6	7.1	6.0	4.5	7.2	8.3	7.4		
North York	8.8	8.0	7.3	7.7	7.3	8.0	7.3	6.5*		
Oshawa	8.9	8.7	8.4	7.2	8.1	10.3	6.9	9.2		
Port Hope	5.2	5.6	7.1	6.5	5.5	7.2	7.0	6.5		
Scarborough	8.6	8.4	8.2	7.0	7.7	7.8	5.6	8.4		
S.S. Marie	7.7	7.0	6.8	7.2	5.1	6.4	8.0	4.6	3.7	6.4
Sudbury	6.9	9.1	8.0	6.4	5.6	7.7	5.3	7.0	7.2	6.7
Thunder Bay	6.4	4.0	4.3	3.5	3.6	2.9	3.2	4.7	4.1	5.1
Toronto	9.5	8.7	8.0	7.3	8.0	9.5	7.2	8.3		7.8
Windsor	9.0	8.3	7.8	9.3	10.4	12.7	9.5	9.5	10.7	9.9
Provincial Mean	8.3	7.9	8.2	7.0	7.3	8.6	7.2	7.7	7.3	8.2

* change of location from Science Centre (34002) to Yonge/Finch (34020)

Section H - References

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